BEST SELLING BOOK

WHITEBOOK OF SEMICONDUCTOR INDUSTRY

All in One Guide to Students and Professionals and Semiconductor Businesses

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Whitebook of Semiconductor Business

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Section: 1

Introduction

As a brain of electronic products, semiconductors (or integrated circuits) play a major role in the digital economy by performing logical operations, controlling electric current, and digitizing and storing data. With the advent of information and communications technology, particularly semiconductors became essential ingredients for computing, communications, energy, automotive, and industrial applications.

The birth history of semiconductors can be traced back to the invention of the rectifier (AC-DC converter) in 1874. Decades later, Bardeen and Brattain at Bell Laboratories in the US invented the point-contact transistor in 1947, and Shockley invented the junction transistor in 1948. This heralded the arrival of the transistor era. In 1946, the University of Pennsylvania in the US built a computer using the vacuum tubes. The computer was so large that its vacuum tubes occupied the entire building, and it consumed a huge amount of electricity and produced a lot of heat. Later, the innovative transistor calculator (computer) was developed, and since then computers have grown by leaps and bounds. In 1956, the Nobel Prize in Physics was awarded jointly to Shockley, Bardeen and Brattain for their contribution to semiconductor research and the development of the transistor.

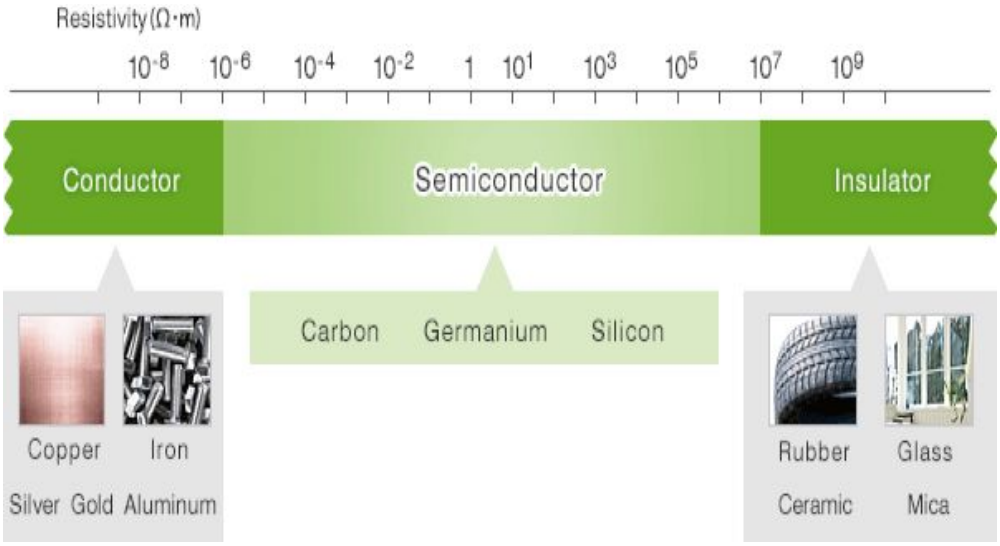
The semiconductor industry grew rapidly following the invention of the transistor. In 1957, it already exceeded the scale of 100 million dollars.

In 1959, the bipolar integrated circuit (ICs) was invented by Kilby of Texas Instruments and Noyce of Fairchild Semiconductor in the US. This invention had a major impact on the history of semiconductors, and it marked the dawn of the IC era. Being small in size and light in weight, the IC was widely used in a variety of electric appliances.

In 1967, Texas Instruments developed the electronic desktop calculator (the calculator) using IC. In Japan, electronic equipment manufacturers released calculators one after another, and fierce “calculator wars” continued until the end of the 1970s. IC integration advanced even further, and the large-scale integrated circuit (LSI) was developed. The technologies continue to advance. The VLSI (from 100 thousand to 10 million electronic components per chip) was developed in the 1980s, and the ULSI (more than 10 million electronic components per chip) was developed in the 1990s. In the 2000s, the system LSI (a multifunction LSI with multiple functions integrated in a single chip) was put into full-scale production. As IC progresses toward high performance and multiple functions, its field of application is expanding broadly. Semiconductors are now used in every corner of our society and support everyday life.

- **Properties of semiconductors**

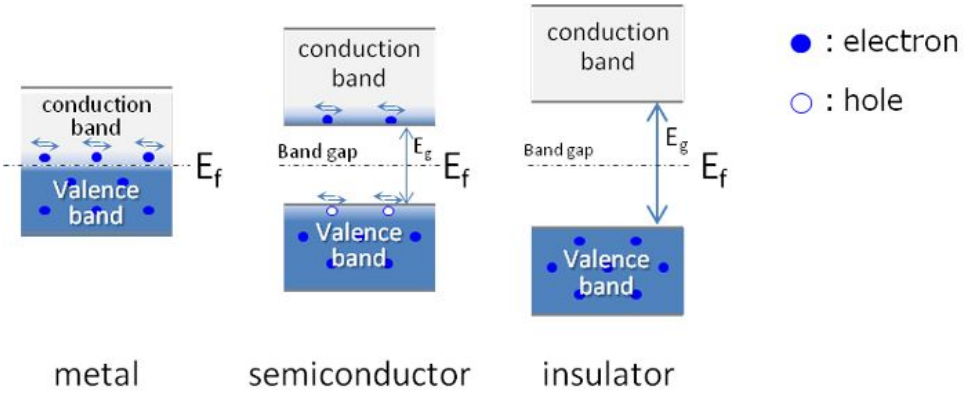
The name “semiconductor” is widely known, but what are semiconductors?
Semiconductors possess specific electrical properties. A substance that conducts electricity is called a conductor, and a substance that does not conduct electricity is called an insulator. Semiconductors are substances with properties somewhere between them.
Electrical properties can be indicated by resistivity. Conductors such as gold, silver and copper have low resistance and conduct electricity easily. Insulators such as rubber, glass and ceramics have high resistance and are difficult for electricity to pass through. Semiconductors have properties somewhere between these two. Their resistivity might change according to the temperature for example. At a low temperature, almost no electricity passes through them. But when the temperature rises, electricity passes through them easily.
Semiconductors containing almost no impurities conduct almost no electricity. But when some elements are added to the semiconductors, electricity passes through them easily.
Semiconductors comprising a single element are called elemental semiconductors, including the famous semiconductor material Silicon. On the other hand, semiconductors made up of two or more compounds are called compound semiconductors, and are used in semiconductor lasers, light-emitting diodes, etc.



Energy Band

An atom is consisting of a nucleus and electrons orbiting the nucleus.

The electrons cannot orbit the nucleus at any distance in the atomic space surrounding the nucleus, but only certain, very specific orbits are allowed, and only exist in specific discrete levels. These energies are called energy levels. A large number of atoms gather to form a crystal, and interacts in a solid material, then the energy levels became so closely spaced that they form bands. This is the energy band.
Metals, semiconductors and insulators are distinguished from each others by their band structures. Their band structures are shown in the figure below.



In metals, the conduction band and the valence band come very closer to each other and may even overlap, with the Fermi energy E somewhere

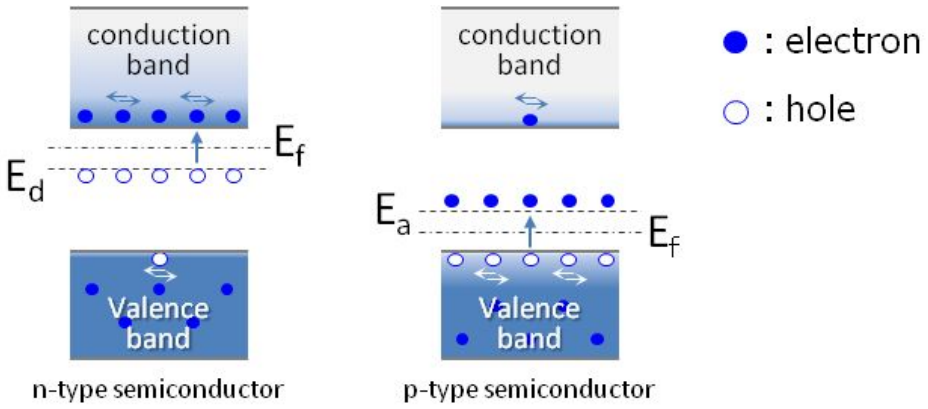
inside. This means that the metal always has electrons that can move freely and so can always carry current. Such electrons are known as free electrons. These free electrons are responsible for current that flows through a metal.

In semiconductors and insulators, the valance band and conduction band are separated by a forbidden energy gap Eg of sufficient width, and the Fermi energy E is between the valence and conduction band. To get to the conduction band, the electron has to gain enough energy to jump the band gap. Once this is done, it can conduct.

In semiconductors at room temperature, the band gap is smaller, there is enough thermal energy to allow electrons to jump the gap fairly easily and make the transitions in conduction band, given the semiconductor limited conductivity. At low temperature, no electron possesses sufficient energy to occupy the conduction band and thus no movement of charge is possible. At absolute zero, semiconductors are perfect insulators, The density of electrons in conduction band at room temperature is not as high as in metals, thus cannot conduct current as good as metal. The electrical conductivity of semiconductor is not as high as metal but also not as poor as electrical insulator. That is why, this type of material is called semiconductor - means half conductor.

The band gap for insulators is large so very few electrons can jump the gap. Therefore, current does not flow easily in insulators. The difference between insulators and semiconductors is the size of the band gap energy. In insulator where forbidden gap is very large and as a result the energy required by the electron to cross over to the conduction band is practically large enough. Insulators do not conduct electricity easily. That means the electrical conductivity of insulator is very poor.

Semiconductor crystal used for IC etc. is high purity single crystal silicon of 99.999999999%, but when actually making a circuit, impurities are added to control the electrical properties. Depending on the added impurities, they become n-type and p-type semiconductors.



Pentavalent phosphorus (P) or arsenic (As) are added to high purity silicon for n-type semiconductors. These impurities are called donors. The energy level of the donor is located close to the conduction band, that is, the energy gap is small. Then, electrons at this energy level are easily excited to the conduction band and contribute to the conductivity.

On the other hand, trivalent boron (B) etc. is added to p type semiconductor. This is called an acceptor. The energy level of the acceptor is close to the valence band. Since there are no electrons here, electrons in the valence band are excited here. As a result, holes are formed in the valence band, which contributes to the conductivity.

- **Semiconductors in everyday life**

How semiconductors are used in everyday life? Since semiconductor itself is not sold in stores as electrical appliances, it may to be hard to understand, but in fact it is used in many electric appliances.

For example, temperature sensors used in air conditioners are made with semiconductors. Rice cookers cook rice perfectly because semiconductors control the temperature precisely. CPUs that operate personal computers are also made with semiconductors. Many digital consumer products in everyday life such as mobile phones / smartphones, digital cameras, televisions, washing machines, refrigerators and LED bulbs also use semiconductors.

In addition to consumer electronics, semiconductors play a central role in the operation of bank ATMs, trains, the internet, communications and other parts of social infrastructure, such as the medical network used for the care

of elderly, among other things. Furthermore, efficient logistics systems help save energy and promote the preservation of the global environment. The number of car-mounted semiconductor devices has been increasing steadily. There are many types of car-mounted semiconductors. Particularly for future ADAS (Advanced Driver Assistance Systems), more semiconductors are expected to be used.

In this way, semiconductors help us to live comfortable lives.

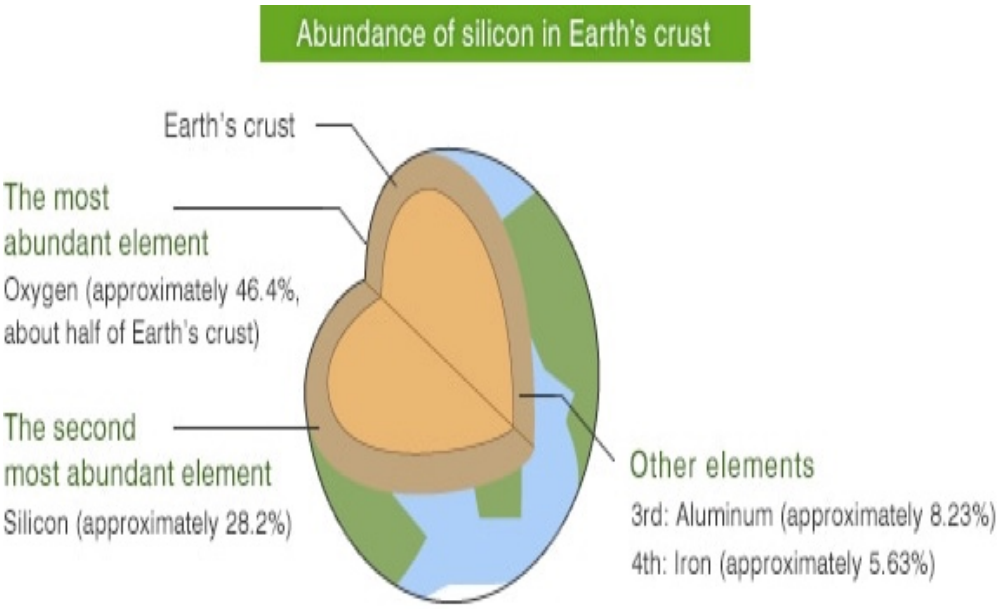
- **The semiconductor material silicon**

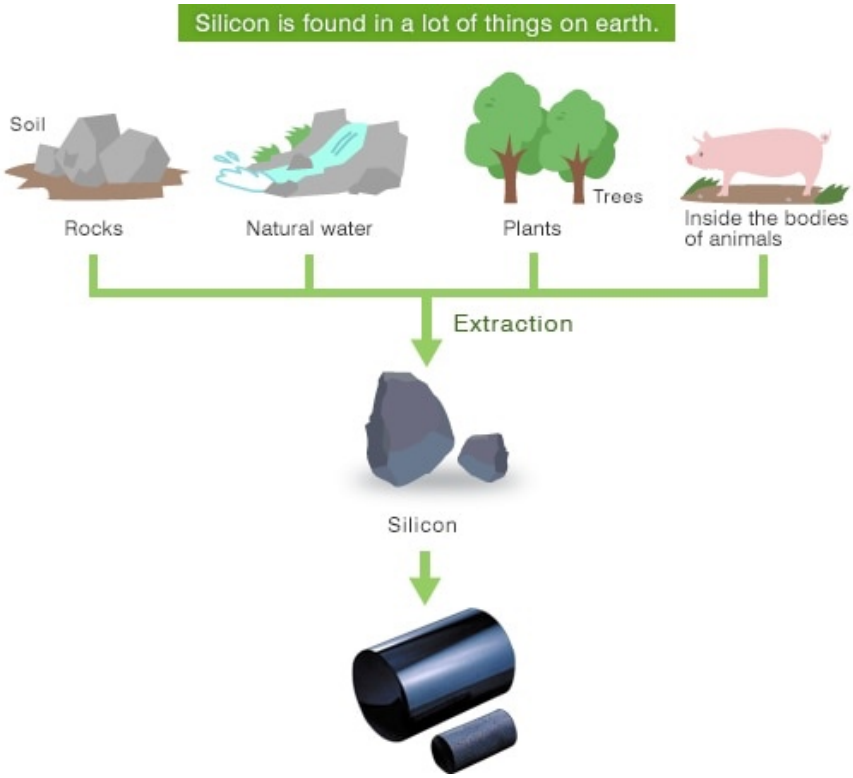
Semiconductors are widely used in familiar electric appliances such as personal computers, televisions, smartphones, digital cameras, IC cards, etc. The material most frequently used in semiconductors is Silicon (chemical symbol = Si). Silicon is the second most abundant element on earth after Oxygen. Most Silicon is found in soil and rock, but Silicon is also contained in natural water, trees and plants.

In nature, however, Silicon is found in the form of compounds with Oxygen, Aluminum and Magnesium. As a result, the Silicon element must be extracted from the compound and purified. Silicon used in a semiconductors such as an integrated circuits (IC) requires a single crystal structure of ultra-high-purity “99.999999999%” (the so-called “eleven nines”) and is refined using various processes after extraction.

A single crystal structure is a structure whereby atoms are arranged in an orderly fashion in three dimensions, and the basic unit of the arrangement is called the crystal lattice. A single crystal is a crystal lattice in an orderly, continuous arrangement. A Silicon crystal lattice has a diamond cubic crystal structure in a repeating pattern of eight atoms. Each Silicon atom is combined with four neighboring silicon atoms by four bonds. Silicon, a very common element, is used as the raw material of semiconductors because of its stable structure.

Purification of Silicon consumes large amounts of power. In Japan, refined Silicon (ingot) with purity of at least 98% is imported from Australia, China and Brazil, where electricity is relatively inexpensive.

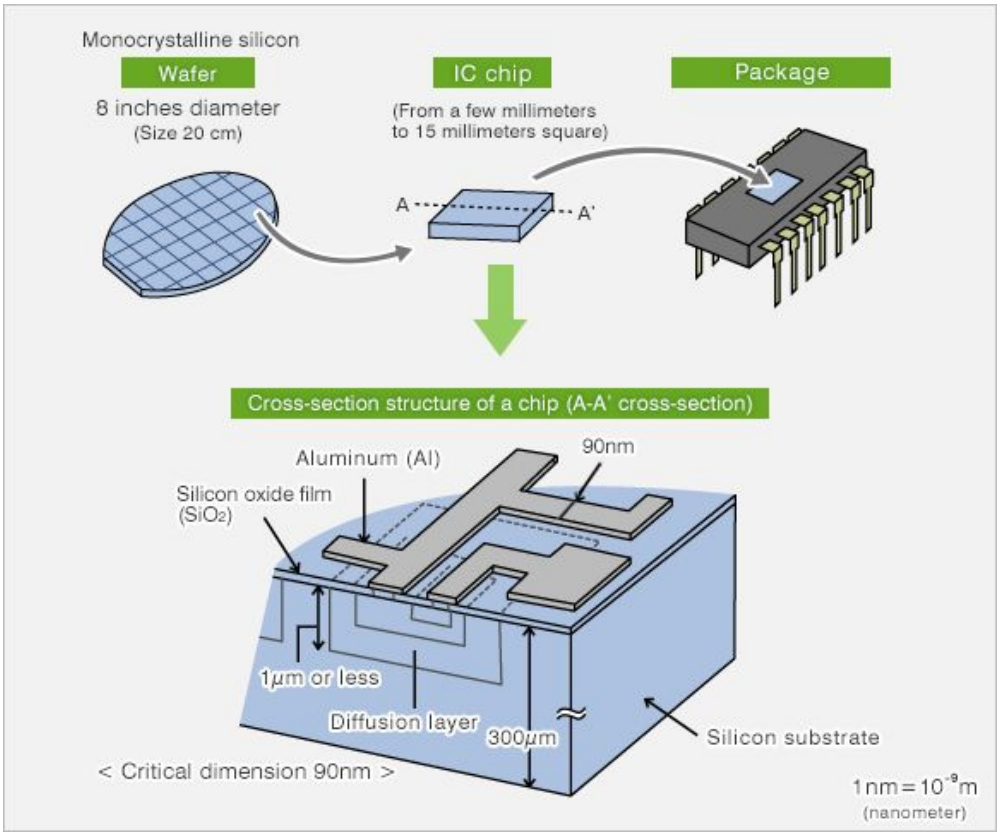

Abundance of silicon in Earth's crust
Earth's crust
The most abundant element
Oxygen (approximately 46.4%, about half of Earth's crust)
The second most abundant element
Silicon (approximately 28.2%)
Other elements
3rd: Aluminum (approximately 8.23%)
4th: Iron (approximately 5.63%)



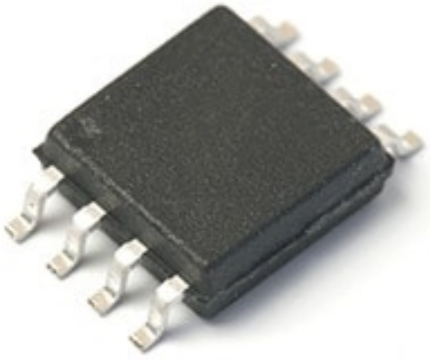
- **Integrated circuit (IC)**

An integrated circuit (ICs) is an electronic device comprising numerous functional elements such as transistors, resistors, condensers, etc. on a piece of silicon semiconductor substrate, and is sealed inside a package with multiple terminals. At present, IC critical dimensions (or smallest dimensions of IC elements) are in the order of 10 nanometers (nm: 10-9m), which is extremely small.
Transistor radios that fascinated boys in the old days consisted of a piece of printed board with discrete transistors, resistors, condensers and diodes inserted, which were wired to each other. The current IC is highly integrated and miniaturized, about 1/55000 of the size and 3 billionths of the area of the transistor radio. Owing to their high integration, ICs with various functions embedded have dramatically enhanced the performance of electronics.
In the manufacturing of ICs, many ICs are made on a silicon wafer and then cut (diced) into numerous IC chips (dies). The IC chips are sealed inside packages because they are too small to be electrically bonded to a printed circuit board, and also because IC chips would get broken if left unprotected.

If you open the cover of a personal computer, you will see objects with multiple legs sticking out. These are the ICs hidden inside the packages.
Depending on the number of components, ICs are classified as LSI (large-scale integration), VLSI very large scale integration), and ULSI ultra large scale integration . Normally the “VLSI” term covers "ULSI".



- **Semiconductor Power Devices and MEMS "Power devices"**



Power semiconductor

While semiconductors like the CPU and the LSI are used for computing and memory, power devices are used for electricity control and conversion. Speaking of semiconductor might imagine the IC. But power devices are semiconductors that can operate under large current and high voltage, in contrast to ICs. For example, the power circuit called an inverter that controls the electric power for running a train is embedded with power devices called a gate turn-off thyristor (GTO) and an insulated gate bipolar transistor (IGBT). These power devices turn the power on/off several hundred times to several tens of thousands times per second. In addition, these power devices can handle high voltage of several thousand volts, enabling the operation of the Shinkansen bullet train.

Inverters embedded with the efficient IGBT and other power devices are used in home appliances such as air conditioners, refrigerators, microwaves, rice cookers and LCD televisions, which are indispensable in our everyday live. They are also used in hybrid cars, fuel cells, solar cells and wind power generation, which are essential for taking measures against global warming. (Speaking of "inverter", it often refers to the entire device which combined with the converter.)

In recent years, SiC and GaN based wide-bandgap power semiconductors have been receiving much attention as the "Next Generation Power Semiconductors". Since these power semiconductors have significantly lower power loss compared to silicon based power devices, these new power devices can improve efficiency of the power supply and reduce the size of equipment. New power semiconductor materials are also expected to improve fuel efficiency of a hybrid car and to save energies of various devices including electric vehicles and trains. As the next generation power semiconductors are currently being commercialized, further improvements are expected in the performance of power electronics products.

"MEMS"

MEMS sensor

MEMS (Micro Electro Mechanical Systems) are ultra-compact systems composed of micro-mechanical components such as sensors, actuators and electronic circuits on a silicon wafer using the microfabrication technology of the LSI (semiconductor) manufacturing technology. MEMS contribute to the ultra-miniaturization of various products, for example digital micro-displays (DMD) of projectors, nozzles inside the heads of ink-jet printers and a variety of sensors such as gyroscopes, pressure sensors, acceleration sensors and flow rate sensors. They are also used in the blood test chips and catheters of medical devices.

In the conventional LSIs, electronic circuit is integrated large quantities on a wafer plane. On the other hand, most distinctive feature of MEMS is that it can be fabricated large quantities of mechanical devices on the wafer. The mechanical devices in MEMS are fabricated with using three-dimensional lamination techniques onto a wafer. The mechanical devices and electrical functions in MEMS are manufactured at the same time. This enables the enhancement of the high performance and large capacity of the LSI. In the future, MEMS will miniaturize sensors and other devices even further and make them even more efficient in terms of power consumption.

"In the future"

Power semiconductor devices and MEMS sensors will be utilized more and more on a variety of products, including smartphones and automobiles. More and more information will be processed at a lower power consumption,

and it is expected the realization of safe, secure and smart society by the sensor network.

Brief History of semiconductors

The transistor was invented at Bell Labs in New Jersey in 1947 by John Bardeen, Walter Brattain and William Shockley. The transistor is at the heart of almost all electronics and so it is one of the most important inventions of the 20[SUP]th[/SUP] century. Shockley fell out of favor with Bell Labs and returned to Palo Alto where he had been brought up. He opened the Shockley Semiconductor Laboratory of Beckman Instruments and tried to lure ex-colleagues from Bell Labs to join him. When he was unsuccessful, he searched universities for the brightest young graduates to build the new company. This was truly the genesis of Silicon Valley and some of its culture that still exists today. Shockley is credited with bringing the silicon to Silicon Valley.

Shockley’s management style was abrasive and caused dissension in the ranks but the final straw was when Shockley decided to discontinue research into silicon-based transistors. Eight people, known as the traitorous eight, resigned and with seed money from Fairchild Camera and Instrument they created Fairchild Semiconductor Company. Almost all semiconductor companies, especially Intel, AMD and National Semiconductor (now part of Texas Instruments), have their roots in Fairchild in one way or another. It was where silicon based integrated circuits began, which as it turns out, is the prevailing technology still in use today.

The second big step, the invention of the integrated circuit, took place simultaneously at Fairchild and Texas Instruments from 1957 to 1959. Jean Hoerni at Fairchild developed the planar transistor then Jack Kilby at Texas Instruments and Robert Noyce at Fairchild developed the integrated circuit.

This turned out to be the big breakthrough. Until that point transistors were built one at a time and wired together manually. The planar manufacturing process allowed multiple transistors to be created simultaneously and connected together simultaneously. By 1962 Fairchild was producing integrated circuits with about a dozen transistors. Much has changed in the intervening years but this same basic principle is how we build today’s chips with billions of transistors.

So those two inventions, the transistor and the integrated circuit, really are the key to electronics today and the ways in which semiconductors affects our lives.

1904: Two-electrode vacuum tube is invented

* The image is for illustration purposes only

Thomas Alva Edison, the inventor of the first practical incandescent light bulb, had also noticed that the direct electric current flowed from a heated metal filament in the bulb to the other electrode only when the latter had a positive voltage. John Ambrose Fleming used this effect (known as the Edison effect) to invent the two-electrode vacuum tube rectifier, which was soon to play an important role in the electrical circuits.

1946: World's first general-purpose computer ENIAC is announced

ENIAC was the largest electronic machine ever made, equipped with some 18,000 vacuum tubes and weighing about 30 tons. It occupied a 160-square-meter room.

The computer consisted of a total of about 110,000 electronic circuit devices.

In contrast, today's microprocessor typically integrates tens of millions of transistors and yet is smaller than the palm of your hand. This astonishing decrease in size started when solid state semiconductors replaced vacuum tubes.

1948: Junction-type transistor is invented

Toward the end of 1947, John Bardeen and Walter Brattain at AT&T Bell Labs developed the point contact transistor, which was the first transistor ever constructed. William Shockley and his team continued with this research,

and announced the invention of the mechanically solid junction-type transistor in June 1948.

Subsequently, integrated circuits (ICs) were invented that packed large numbers of transistors into a small chip, followed by large-scale integrated circuits (LSIs) with an integration level of 1,000-100,000 components or more on a chip.

1955: Japan's first transistor radio is released

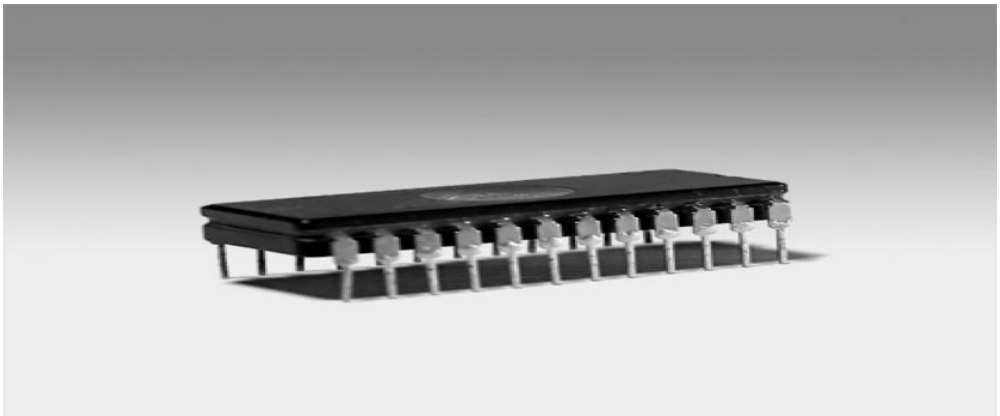
Early broadcast radio receivers used vacuum tubes. By replacing vacuum tubes with semiconductor transistor devices, radios became smaller, lighter, and less power consuming. Tokyo Tsushin Kogyo (Tokyo Telecommunications Engineering Corporation; now Sony) released Japan's first transistor radio TR-55 in 1955. While attempting to improve the yield of a transistor manufacturing process, the company's research team discovered the quantum mechanical effect known as tunneling.

1957: Esaki diode is invented

While pursuing a research project for creating faster transistors, Leo Esaki made an artificial structure consisting of two layers of different semiconductor materials separated by a thin dielectric layer of 10 nm or less, and discovered that the electron tunneling effect occurs within this structure.
The first electronic device that applied this effect was the Esaki diode, which became a major springboard for subsequent development of LSIs.

1959: Kilby patent is filed

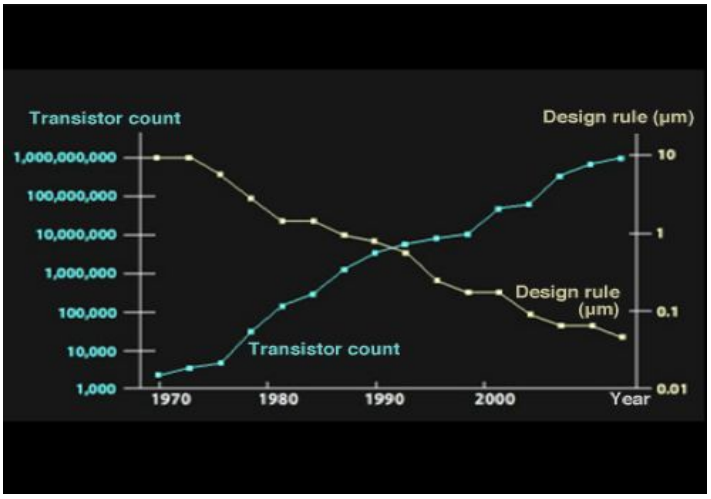
The Kilby patent refers to



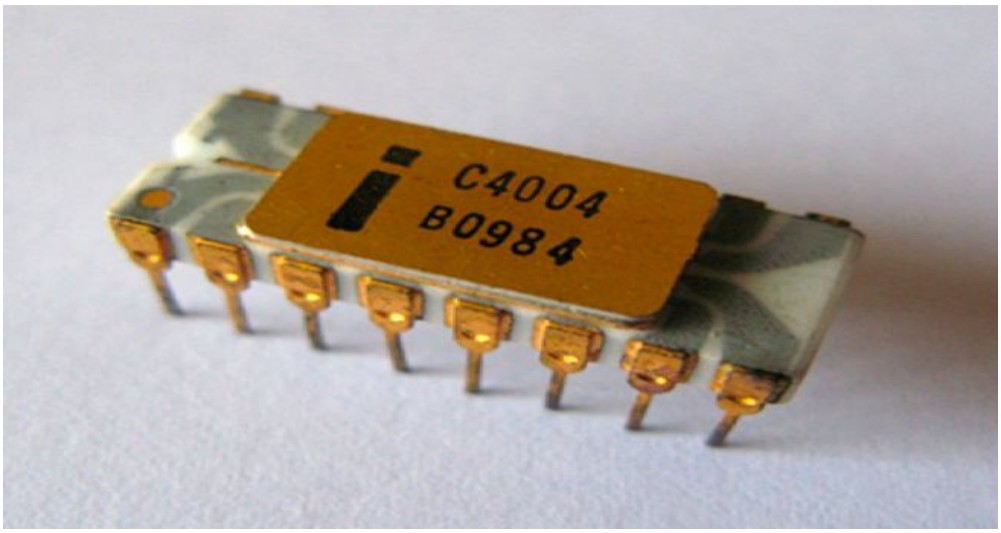
the patent on the basic concept of the integrated circuit developed by Jack St. Kilby at Texas Instruments (TI). The far-reaching patent yielded huge royalties to TI. Because Japan had originally delayed granting this patent for many years, its expiration date in Japan was as late as in 2001. As a result, Japanese semiconductor manufacturers were charged with large amounts of licensing fees for some of their products.

1965: Moore's law is announced

In 1965, Gordon Moore (who later became a co-founder of Intel) predicted that the integration rate of LSIs would double every 18 months, implying that it would quadruple in three years and become 1,000-fold denser in 15 years. The prediction, known as Moore's law, was based on the analysis of historical trends in the computer manufacturing industry. The proposition was widely accepted in the semiconductor and computer industries, and the reality turned out to be almost exactly as Moore had foreseen.



1971: Intel 4004 is released



* Photo credit: Dentaku Museum

Intel 4004 was the world's first single chip microprocessor. It was originally developed on the request of Busicom Corporation in Japan as an LSI for its electronic calculator. Intel's Ted Hoff proposed the idea of universal logic processor, which was taken up by Masatoshi Shima at Busicom and Federico Faggin at Intel who completed the chip design. Attracted by the potential versatility of this chip, Intel obtained the sales rights to the product.

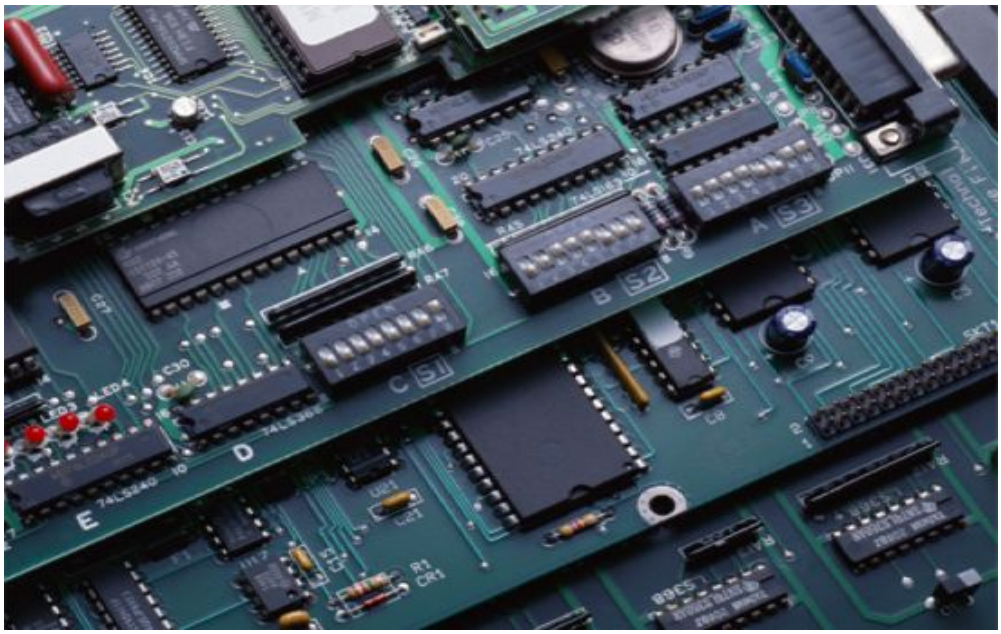
1977: World's first personal computer Apple II is released

Although many consider the Altair 8800 to be the world's first personal computer, its manufacturer called it a minicomputer along with other designations such as microcomputer and home computer. In contrast, Apple's Steve Jobs used the term "personal computer," which took hold with the commercial success of the Apple II.

1980: Flash memory is invented

Flash memory is a rewritable semiconductor memory device that is non-volatile (i.e., it retains the information when power is turned off). Unlike previous rewritable memory that could only erase the information one byte at a time, flash memory was designed to erase the entire block of data at once, and to reduce the cost per bit by 75% or more.

Flash memory was invented in 1980 by Fujio Masuoka (then a Toshiba employee). Today, flash memory is found in personal computers, mobile phones, digital cameras, IC cards, and many other applications that we use



every day.

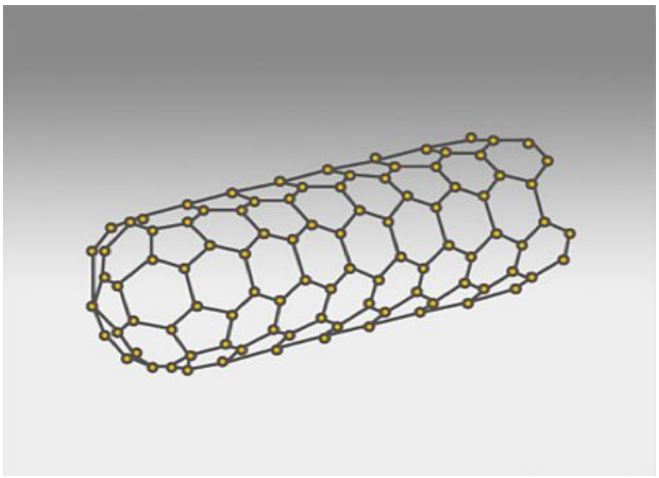
1983: Family Computer is released

The advancement in semiconductor technology has revolutionized family entertainment as well. In 1983, Nintendo released a video game console fitted with an 8-bit CPU. The Family Computer (Famicom) became a smash hit on the back of the popularity of Super Mario Bros., a game developed by Nintendo for this platform. Encouraged by Famicom's success, the company released a 16-bit game console known as Super Famicom in 1990.

The video game market thrived as palm-sized mobile platforms and other variations also entered the fray, and the consoles have become more advanced than ever.

1991: Carbon nanotube is discovered

The evolution of the semiconductor can no longer be discussed without referring to the advancement in nanotechnology. The discovery of the carbon nanotube by Sumio Iijima in 1991 was a pivotal event in this field.



Carbon nanotubes have many excellent properties, including over 1,000 times greater electric current density and 10 times better room-temperature thermal conductivity than copper. That makes carbon nanotubes a promising successor to silicon as semiconductor scaling continues.

1993: First practical blue LED developed

Light-emitting diodes (LEDs) have been considered ideal for making display panels, as they consume very small power to produce light. The application required three primary colors (red, green, and blue), however, and there had been no practical technology to manufacture blue LED until 1993, when Nichia Corporation and Shuji Nakamura developed the blue LED technology.

Their achievement made full color LED displays possible, as well as the blue laser technology that enabled advanced DVD recorders and other applications.

1995: Sharp releases liquid crystal display TV "Window"

In 1982, Epson released the world's first LCD television. It was a digital watch with a 1.2-inch reflective LCD that doubled as a TV. Epson went on to release a pocket color TV with a 1.2-inch transmissive TFT LCD in 1984. No LCD TV with a reasonably large screen was available until 1995, when Sharp introduced a 10.4-inch TFT model as part of the Window series.

2002: Earth Simulator records world's fastest processing speed of 35.86 TFLOPS

The Earth Simulator
Built by NEC for the Japan Aerospace Exploration Agency, the Japan Atomic Energy Research Institute and the Japan Marina Science and Technology Center, the Earth Simulator (ES) was the fastest supercomputer in the world from 2002 to 2004.
and AMD to in
the processor'
performance
Windows 7.
Maybe Microsoft boss, Steve Ballme
also address various tops and flops
company in his Keynote at the Cons
Electronics Show CES 2012 – the la
kind, as, to the surprise of the indust
Microsoft is saying farewell to this sh
list of flops got a little longer in
mid-December, with the "update to c
the performance of AMD Bulldozer C
(KB2592546). In the description, Mi
explains that, until now, the performa
the AMD Bulldozer CPU has been w
than expected.

The Earth Simulator was a highly parallel vector supercomputer built under the auspices of the then Science and Technology Agency. Designed to study global climate change and the mechanism of strata shifting and diastrophism, the Earth Simulator set the world record performance of 35.86 TFLOPS running the LINPACK benchmark in June 2002. The performance, equivalent to about 36 trillions of floating-point operations per second, was almost five times higher than the runner-up—the IBM ASCI White system. The Earth Simulator maintained the top position on the TOP500 list for about three years.

The defeat was dubbed the Computnik crisis in the U.S., as it was reminiscent of the shocking success of the Soviet satellite Sputnik. Determined to push back, the U.S. government set up a national supercomputer project and regained the top spot in three years.

*Image Source: Screen shot of an article on the TOP500 website

2004: Graphene creation experiments prove successful

Graphene, or an atomic-scale sheet of carbon atoms, is attracting attention as a high-performance semiconductor material that could one day replace silicon. Its existence was predicted as early as in the 1940s, but it was much later that graphene was isolated. In 2004, Andre Geim and Konstantin Novoselov applied clear adhesive tape to a block of graphite, cleaving a thin layer of graphene.

Graphene is expected to enable highly efficient solar cells, very sensitive touch panels, and many other useful applications.

2007: Apple announces the iPhone

The announcement of iPhone by Steve Jobs on January 9, 2007 completely changed the landscape of the global mobile phone industry. The iPhone was designed to use what he called "the best pointing device in the world"–our fingers. Featuring a 3.5-inch widescreen multi-touch display panel, the device realized diverse functionality and ease of use at the same time.

2010: Apple announces the iPad

Steve Jobs introduced Apple's fourth innovation after Macintosh, iPod, and iPhone on January 27, 2010. The iPad, according to him, was a multi-touch information device that would straddle between laptops and smartphones. The iPad was central to Jobs' vision of media integration, and became the key to Apple's consumer market strategy.

November 2011: K computer achieves world's fastest processing speed of 10 PFLOPS

The K computer, Japan's next-generation supercomputer that has been developed under the guidance of the Ministry of Education, Culture, Sports, Science and Technology, recorded the performance of 8.16 PFLOPS running the LINPACK benchmark in June 2011. The feat returned Japan to the top spot on the TOP500 list, years after the Earth Simulator won the honor. In November 2011, the K computer again claimed the top spot with the performance of 10 PFLOPS (10 quadrillion floating-point operations per second), and is still leading the list as of March 2012.

League of TOP 1
京
K computer
The K computer – named for the Japanese word "kei" (京?), which stands for 10 quadrillion[1] – is a supercomputer being produced by Fujitsu at the RIKEN Advanced
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LINPACK is a software library for performing numerical linear algebra on computers. It is used for measuring the performance of supercomputers from around the world and determining the TOP500 ranking.

* Image Source: Screen shot of an article on the TOP500 website

2013: Google Glass beta test starts

VR and AR are technologies for making computer-generated environments perceptible to humans just as they perceive real-world information. VR generates purely artificial environments by means of computer graphics, whereas AR overlays computer-generated images on real-world scenes to extend or augment reality. With the proliferation of personal computers and smartphones, VR and AR came to be applied to consumer services in the first decade of the 2000s. Google began beta testing its wearable AR tool Google Glass in 2013, setting in motion the trend for applying AR to wearable computers such as smartphones, smart glasses, and smart watches.

2015: Ken Sakamura receives ITU 150 Award

Connecting via the Internet various objects embedded with microprocessors and sensors was an idea that has been entertained since as early as the 1980s. Computer scientist Ken Sakamura, one of the pioneers in the field, dubbed this concept "ubiquitous computing," putting forward an open computer system architecture known as TRON.

It was much later, around 2014, that the concept came to be popularly known as the Internet of Things (IoT). Today, IoT is expected to significantly improve industrial efficiency and expand the potential of businesses. In 2015, the International Telecommunication Union (ITU) honored Sakamura with its 150th anniversary award.

2016: AlphaGo defeats a human Go master

Artificial intelligence (AI) was first established as a research discipline at a conference in Dartmouth College in 1956. With the introduction of commercial databases in the 1980s, investment in AI research began to gain momentum. As the processing power of computers has dramatically increased over the past years, AI applications capable of deep learning are emerging that can uncover hidden relationships and patterns in big data in real time. In 2016, the AlphaGo AI program developed by DeepMind defeated the human world champion in the game of Go.

Section: 2

Trends in Semiconductor industry

Overview

The number of semiconductor components used in our daily lives is expanding constantly. Chips form the essential core of many cutting-edge technological devices such as smartphones, tablets, flat-screen monitors and television sets, sophisticated cars, new aircraft, and many medical devices. As a consequence, the semiconductor industry has been growing for 40 years. However, almost no other industry swings as dramatically in relation to overall economic developments. So, will the golden era of the semiconductor industry continue? Have semiconductor companies learned and prepared from the last downturn during the financial crisis in 2008–09?

How will the market for chips develop in the next few years? Which business model will prove to be robust during the crisis and beyond? Where are the current opportunities? What are the critical factors of success?

Global Semiconductor Market

The semiconductor industry has been growing virtually nonstop for 40 years, with global sales increasing at an average compound annual growth rate (CAGR) of about 9% p.a., all despite several downturns in the economy, the bursting of the internet bubble in 2001, and the financial crisis of 2008–09. Since the worst of the financial crisis, the market has been recovering. However, concerns about European sovereign debt, European banking and the future of the Euro, as well as the United States' federal deficit and sluggish economic growth, all conspire to form dark clouds on the horizon which may foretell even greater problems for the global economy.

Apart from its high market growth, the semiconductor industry has been characterised by rapid technological innovation, perhaps best expressed by the often-quoted (and often misunderstood) Moore's Law, which postulates that the number of transistors on a single computer chip doubles every 24 months. While
it has long been predicted that Moore's Law would face insurmountable physical limitations, it now seems as though changes in the production processes and new technologies may sustain this pace longer than many (including Dr Moore) believed. The third characteristic of the semiconductor industry is its need for huge amounts of capital to support both growth and technological progress.

Can the industry's historic high market growth be sustained? Is technological progress slowing due to physical limitations in scaling feature sizes? And how did the recent financial crisis influence the further development of this industry?

We believe the semiconductor industry will continue to grow during the next few years, though at a slower pace than in previous years. In our analysis, we do not assume another economic downturn, despite current issues in the US and European Union. We further believe that scaling down of semiconductor feature sizes will continue and that technological progress will sustain its high pace. We do not expect substantial change within the next few years.

Findings for the global semiconductor market:

- Current market conditions and outlooks are mixed for the next few years, largely because of the fragile global economic outlook.

- The automotive and industrial markets for semiconductors offer significant growth potential.

- The automotive market will be driven by the number of vehicles produced in Brazil, Russia, India and China, and by an increase in the average semiconductor content per vehicle.

- The industrial sector is growing because of increasing energy demands, a continuing trend toward renewable energies and the expansion of high-speed rail transportation.

- The data processing application market is driven by accelerating tablet sales, and the communications market by the still-strong unit sales of smartphones. Consumer electronics also benefit from a growth in units sold, particularly in digital set-top boxes.

- China will cement its dominant position and increase its market share of global semiconductor sales to half of the worldwide market by 2015.

- To meet global demands, global production capacity for semiconductors will increase.

- Overall production capacity is sustaining progress toward smaller feature sizes and larger wafer diameters.

- Operating profitability is back on the positive side of the ledger, except in the memory and back-end processes subsectors, which face strong competition and cycles of overcapacity.

- Working capital is back to normal levels.

We believe that these developments will have significant implications on the landscape of the semiconductor industry. The need for capital and the high pace
of innovation means that companies are increasingly specialising in individual elements of the value chain – such as fabless companies (those without production facilities) that design chips and foundries that specialise in semiconductor production. Integrated device manufacturers (IDM), which cover the entire value chain, are increasingly adopting a “fab-light” strategy, in which some areas of production are outsourced to foundries. On the other hand, we see a trend towards integrating more semiconductor features on a single chip. Only companies with a broad spectrum of product know-how will be capable of doing this. We believe that both movements in the semiconductor ecosystem – the disaggregation of the value chain and the trend toward more features on single chips – will have a significant impact on the M&A activity in the coming years.

As China’s industry demands ever-increasing semiconductor content, semiconductor companies must have a compelling strategy for doing business in China. This includes a coherent plan to access the market in the private and public sectors and the need to deal with intellectual property (IP) issues.

The global semiconductor market sustains growth.

After the global economic crisis peaked in 2009, the semiconductor market recovered quickly and global sales reached a record high in 2010. While billings fell by 11% from 2007’s peak to 2009’s trough, sales then recovered by a remarkable 33% from 2009 to 2010, a pace never before achieved. This more than compensated for previous losses. We expect further progress until 2015, albeit at a slower pace, with an average CAGR from 2010 to 2015 of 7.4% for the overall market.

The global semiconductor market is fuelled by technological developments, good growth prospects in automotive and industrial markets and by China leading the way as the growth engine. At present, consumption in China accounts for more than 40% of global semiconductor revenues, and we anticipate that by 2015 its share will reach 50%. India, Russia and Brazil may play a future role in the semiconductor sector, but with substantially smaller shares than China’s.

Semiconductor companies may benefit by focusing on application markets with above-average growth prospects in the automotive and industrial sectors. A strong presence in China will help them leverage the nation’s huge growth potential.

Current conditions and outlook are mixed

Global semiconductor sales depend on a number of economic and non-economic conditions, as shown in Figure 1. The semiconductor sector is linked to application markets, which themselves are diversified. Major application markets for semi- conductors are: data processing (including personal computers, laptops, servers and tablets); communications (including fixed-line telephone systems, broadband internet, mobile phones, smartphones and more); consumer electronics (television sets, music players, gaming consoles and household appliances); automotive, comprising both light vehicles and trucks; and industrial (including infrastructure, rail services, the military, fossil and regenerative energy, smart grids, etc.). As a consequence, the overall state of the global economy is a key determinant for the state of the semiconductor sector, as demonstrated by a strong correlation between the growth rate of global gross domestic product (GDP) and the growth rate of global semiconductor sales.

Current economic conditions are mixed for the semiconductor sector. Dangers stemming from the high leverages of Greece, Italy, Portugal, Ireland and other European nations, as well as the high debt levels in the United States, leave their marks in the economic forecasts. According to “The World Economic Outlook of
the International Monetary Fund” (from which all the economic data, as of September 1, 2011, in this remaining paragraph is taken) GDP in the US is expected to grow by 1.5% in 2011 and 1.7% in 2012 and in the Eurozone by 2.0% in 2011
and 1.5% in 2012. This forecast incorporates the current status of the debt crisis in the Eurozone and deficits in the US. Japan’s economy is expected to shrink in 2011, with its GDP falling by 0.5% in 2011, but growing by 2.3% in 2012. Among the BRIC nations, GDP is expected to increase in Brazil by 3.8% in 2011 and 3.6% in 2012;

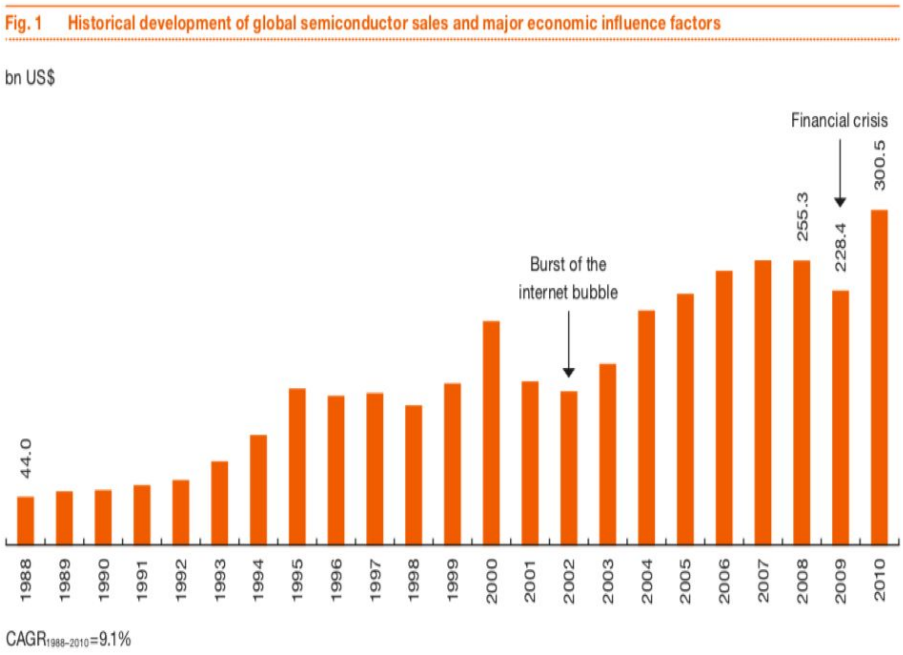
in Russia by 4.3% in 2011 and 4.0% in 2012; in India by 7.8% in 2011 and 7.5% in 2012; and in China by 9.5% in 2011 and 9.0% in 2012. This already implies where the growth of semiconductor demand will be highest: the hunger for semiconductor components in the BRIC countries will fuel the global demand.

the distinct cycles of semiconductor sales closely mimic those of global economic cycles. Despite sharp drops in global sales when the internet bubble burst in 2001, and again after

the financial crisis of 2008–09, global semiconductor sales grew by a CAGR of approximately 9% annually from 1988 until 2010. For the last couple of

years, 2009 to 2010, global semiconductor sales quickly recovered and reached a record high of US$300 billion in 2010.

Major economic influence factors: Production capacity, cyclicity, technology, government aid, global economy, customer demand and financing.



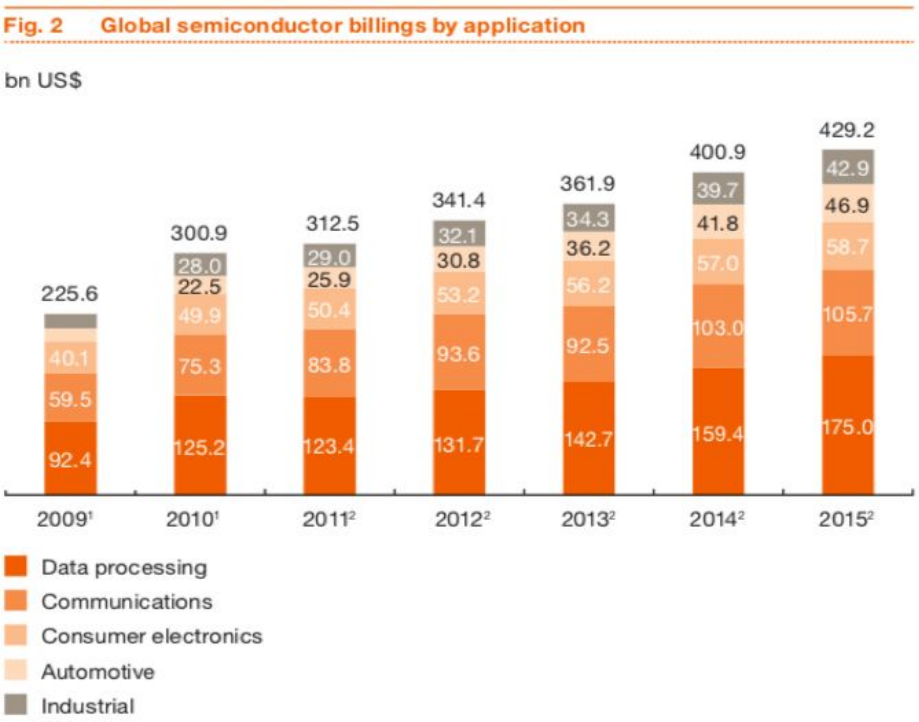
Source: SIA.

In summary, despite all the economic risks and the potential effects of the debt crisis in the Eurozone, and the deficits and sluggish economy in the US, growth prospects for the global semiconductor sector are positive.

Growth potential particularly in automotive and industrial sector

Figure 2 depicts global semiconductor sales by application market for historical
and forecast years from 2009 through to 2015. As Figure 1 shows, semiconductor sales recovered quickly in 2010 from the trough in 2009, which had reflected the financial crisis. Global semiconductor sales grew by more than 30% in 2010 from the previous year's levels. Growth is expected to continue until 2015, but at a slower pace: CAGR from 2010 to 2015 is expected to be 7.4% overall. The application markets with the largest growth rates are automotive and industrial, with a CAGR of 15.8% and 8.9% respectively, in the years between 2010 and 2015. With increasing sales of smartphones and tablets as one important growth driver – though market saturation may come within the next five years – growth figures within the communications sector for semiconductors, at 7.0%, are comparably high as well

At the lower end of the spectrum are consumer electronics and data processing; we expect neither to achieve a substantial innovation breakthrough nor extra-ordinary revenue growth and forecast only moderate growth of 3.3% and 6.9%, respectively. Consumer electronics units are growing exponentially, but declining price is pushing down revenue growth. Please also note that we capture semiconductor components for tablets – a major growth driver – in the data processing and not in the consumer electronics segment.



Global Market Share Country Wise (THE U.S. SEMICONDUCTOR INDUSTRY HAS NEARLY HALF THE GLOBAL MARKET SHARE)

	CAGR 2009–2015	CAGR 2010–2015
Data processing	11.2%	6.9%
Communications	10.1%	7.0%
Consumer electronics	6.6%	3.3%
Automotive	20.0%	15.8%
Industrial	15.7%	8.9%
Total	11.3%	7.4%

[1] actual figures
[2] forecast

Source: Gartner (actual figures), PwC analysis.

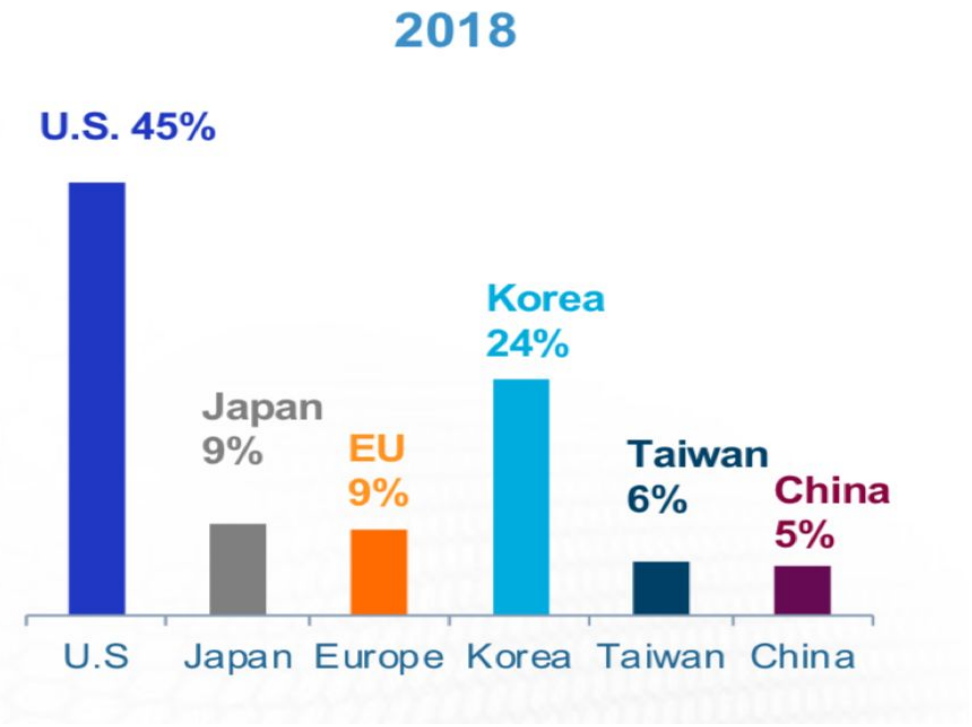
The U.S. semiconductor industry experienced a significant loss in global market share during the 1980s. In the early 1980s, the U.S.-based producers held more than 50 percent of worldwide semiconductor sales. Due to intense competition from Japan-based firms, the effect of illegal "dumping“, and a severe industry recession in 1985 to 1986, the U.S. industry lost a total of nineteen worldwide market share points, and had ceded global industry market share leadership to the Japanese semiconductor industry.

The U.S. industry rebounded over the next 10 years, and by 1997, it had regained its leadership position with over 50 percent global market share, a position the industry continues to hold today. U.S. semiconductor firms have maintained their competitive edge in microprocessors and other leading edge devices, as well as continued to lead in a range of other product areas. In addition, U.S. semiconductor firms maintain a leading position in R&D, design, and process technology. Today, U.S.-based firms have the largest market share with 45 percent. Other countries’ industries have between 5 and 24 percent global market share.

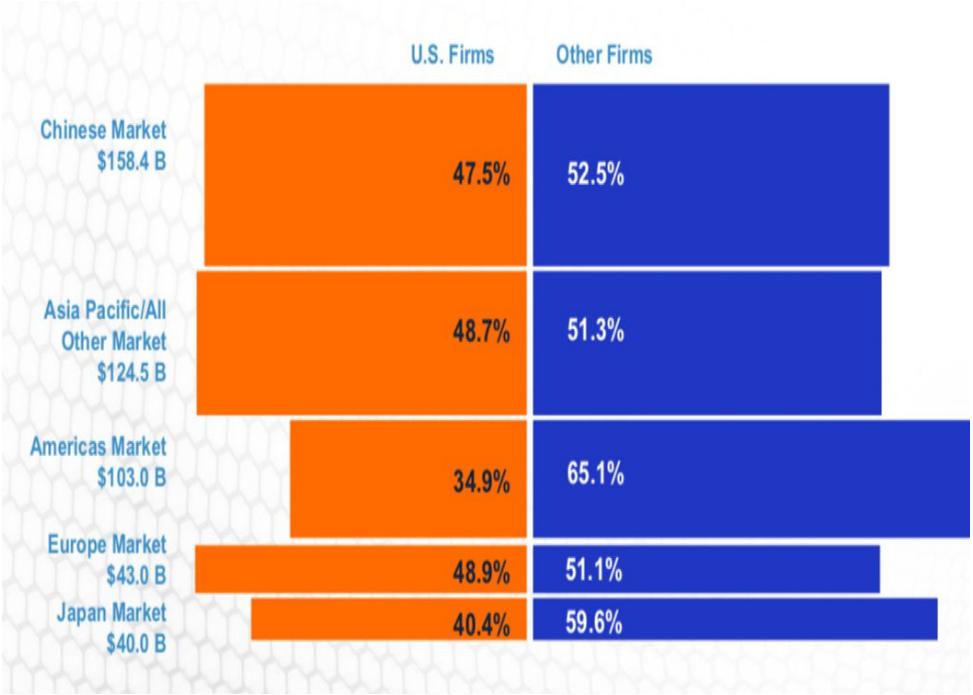
Regional Share of Semiconductor Industry

In 2018, semiconductor firms based in the United States held 45 percent of the total semiconductor market, the most of any countries’ semiconductor industry. In all major country and regional semiconductor markets, U.S. headquartered companies also held sales market share leadership.

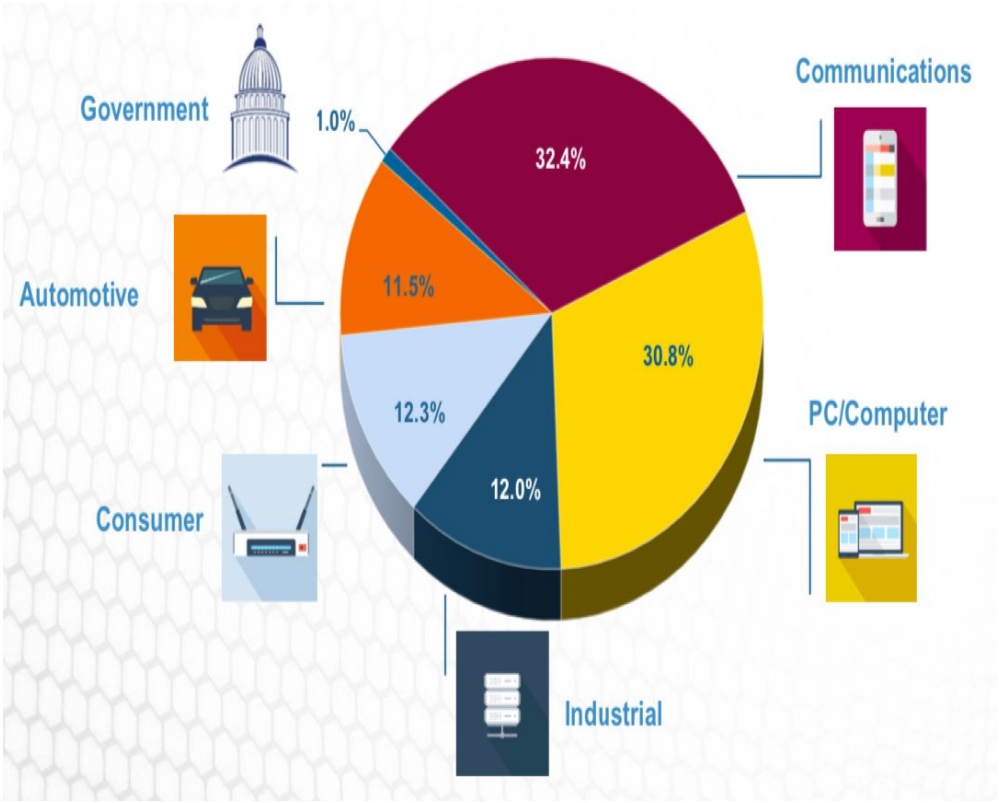
Consumers of Semiconductors



The vast majority of semiconductor demand is driven by products ultimately purchased by consumers – be they laptops or communication devices such as smartphones. Increasingly, consumer demand is driven in emerging markets including those in Asia, Latin America, Eastern Europe and Africa.



2018 Total Global Semiconductor Market: $469 Billion Percent of Semiconductor Demand, by End Use

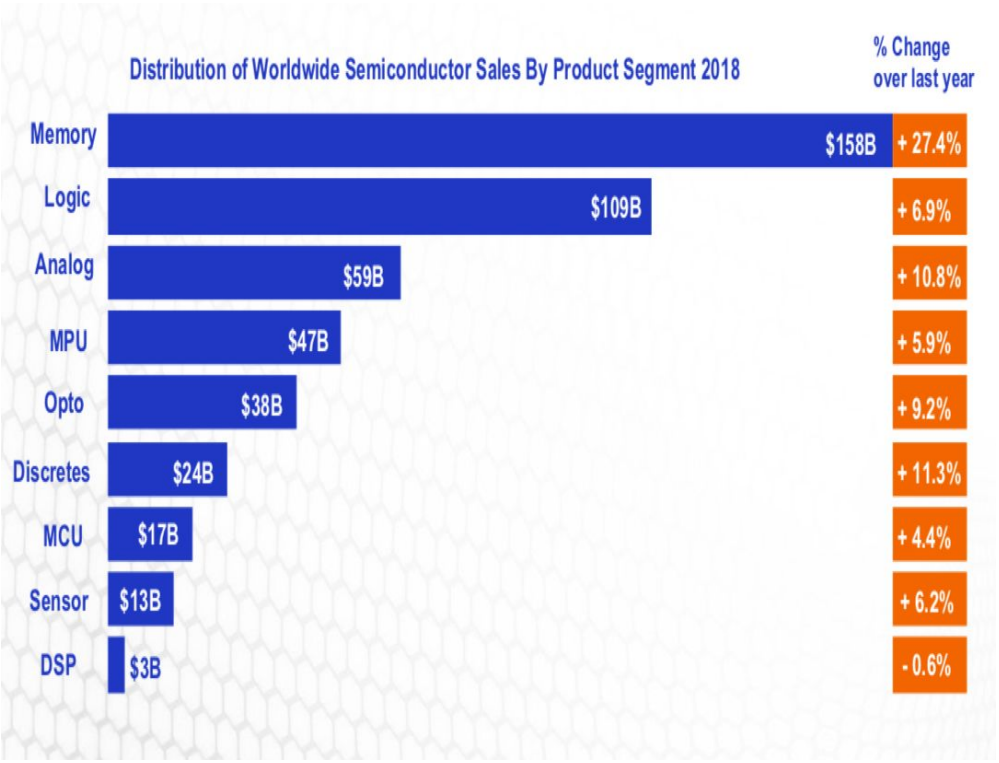


GLOBAL SEMICONDUCTOR SALES ARE DIVERSIFIED BY TYPE OF PRODUCT SOLD

Semiconductor technology has rapidly evolved as the industry develops more advanced product and process technologies for applications in end-use industries. In recent years, the largest segments of the worldwide semiconductor industry have been memory, logic, analog, and MPU.

In 2018, these products accounted for 80 percent of semiconductor industry sales.

Asia Pacific Market



(ASIA PACIFIC IS THE LARGEST REGIONAL SEMICONDUCTOR MARKET, AND CHINA IS THE LARGEST SINGLE COUNTRY MARKET)

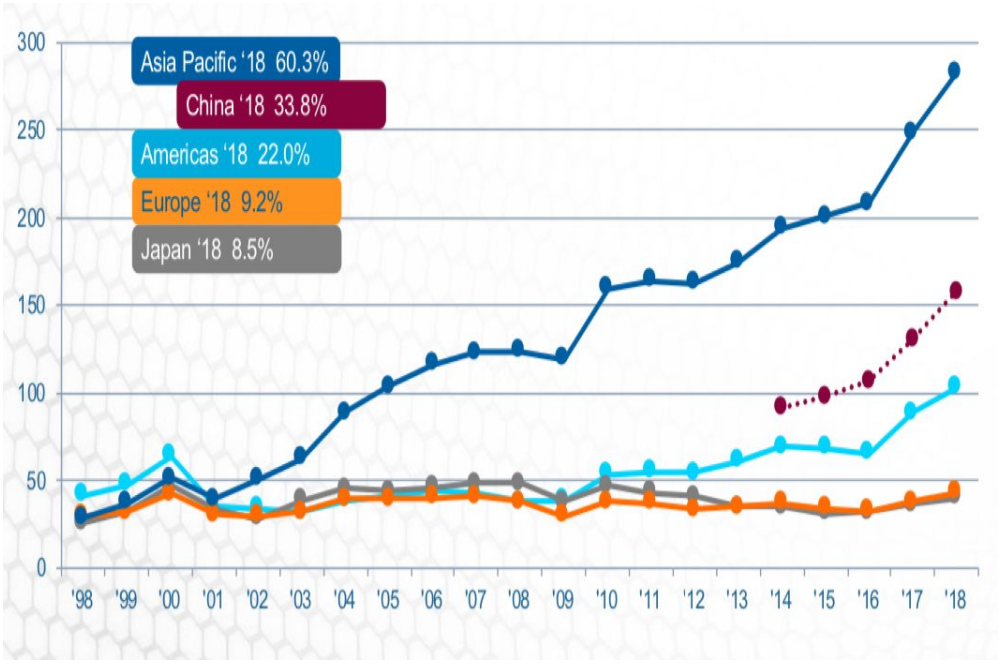
In 2001, the Asia Pacific market surpassed all other regional markets in sales, as electronic equipment production shifted to the region. It has multiplied in size since then - from $39.8 billion to over $282 billion in 2018.

By far, the largest country market within the Asia Pacific region is China, which accounted for 56 percent of the Asia Pacific market and 34 percent of the total global market.

This data reflects sales of semiconductors to electronic equipment makers only – final electronic products containing semiconductors are then shipped for consumption around the world.

Global Regional Semiconductor Market ($Billion)

Impact of Technology on Semiconductor Market



Semiconductors are essential technology enablers that power many of the cutting-edge digital devices we use today. The global semiconductor industry is set to continue its robust growth well into the next decade due to emerging technologies such as autonomous driving, artificial intelligence (AI), 5G and Internet of Things, coupled with consistent spending on R&D and competition among key players.

East Asia (Mainland China, Japan, South Korea and Taiwan) is where some of the world's most important semiconductor players are located. The region has become a hotspot for the semiconductor industry due to its burgeoning economy, therise of mobile communications and growth in cloud computing. China, in particular, commands almost half of overall market value, split roughly 50-50 between domestic demand and Taiwan-based, world-leading ODMs (e.g. Foxconn and Quanta) or foundries (e.g. Taiwan Semiconductor Manufacturing Company [TSMC]) serving global clients. China also aspires to a self- sufficient semiconductor industry and ascension to become a global powerhouse at the same time. Japan, on the other hand, is an important supplier of semiconductor materials, high-end equipment and special semiconductors. Meanwhile, South Korea has a commanding lead in the global HBM (high bandwidth memory) DRAM (dynamic random-access memory) market.

M&A activity in the semiconductor industry has already peaked and specialized verticals are becoming the primary focus. Japan and Korea are seeking to revive their industries through acquisitions, while the continuing trade war and disputes over intellectual property will hamper China's ambition to go on a global spending spree. The semiconductor sector's growth trajectory will flatten somewhat as demand for consumer electronics saturates. However, many emerging segments will provide semiconductor companies with abundant opportunities, particularly semiconductor use in the automotive sector and AI.

In the automotive sector, the adoption of safety-related electronics systems has grown explosively. Semiconductor components that make up these electronic systems will cost USD600 per car by 2022. Automotive semiconductor vendors will benefit from a surge in demand for various semiconductor devices in cars, including microcontrollers (MCUs), sensors and memory. Automation, electrification, digital connectivity and security will result in the addition of more semiconductor content to automotive electronics and subsystems in the next decade.

The AI semiconductor scene has seen a race not just at the application level, but also at the semiconductor chip level, where different architectures are vying for a piece of the pie. The cloud is the biggest market for AI chips, as their adoption in data centers continues to increase as a means of enhancing efficiency and reducing operational cost.

Finally, China has become a source of income for top global semiconductor companies, many of which generate over half of their revenue from China. Multinationals trying to access the Chinese market should consider a multitude of factors such as policies, technologies, marketing, logistics and global strategies. It is imperative for a multinational to realize the position it is in before entering China to come up with the best entry strategy.

Consumption of automotive electronic components for safety, infotainment, navigation and fuel efficiency will increase for years to come due to ever-more electronic components being applied in advanced safety features added to vehicles. Among applications driving semiconductor growth, advanced driver-assistance systems (ADAS) will have the largest increase. They will drive demand for ICs (Integrated Circuits), MCUs and sensors.

Industrial electronics encompass security, automation, solid-state lighting, transportation and energy management. Security is the most substantial driver of industrial electronics. New memory technologies enhance the energy savings, security and functionality of IoT devices.

Head mounted displays will be the main driver of semiconductor growth in consumer electronics. In addition, wearables and smart watches will be new point of growth. However, other consumer electronics markets, such as DVD and portable media players, will see sharp declines. Hence, the overall revenue increase of consumer electronics will be somewhat limited.

Data processing electronics include computing and storage. Storage, especially SSDs (solid-state drives), will account for the largest increase. As the price declines seen in 2018 continue, the trend towards greater SSD adoption and increased average capacity will retain strong momentum; particularly in enterprise SSDs as data center demand will remain a key driver.

Communication electronics include wired and wireless electronics. In wireless electronics, traditional phone and cellular modems will experience large declines, while smart phone demand will increase only slightly. Revenue growth from the wireless market could be quite slow. In wired communication electronics, enterprise WANs (wide area networks) deployed as appliances should be the fastest- growing segment.

APAC appetite remains strong

The Asia Pacific region will remain the world's biggest market for semiconductor consumption. An increasing proportion of Chinese products, which is stimulating the growth of the whole Asia Pacific market, will be the major contributing factor. In addition, more M&A will benefit semiconductor sector growth going forward.

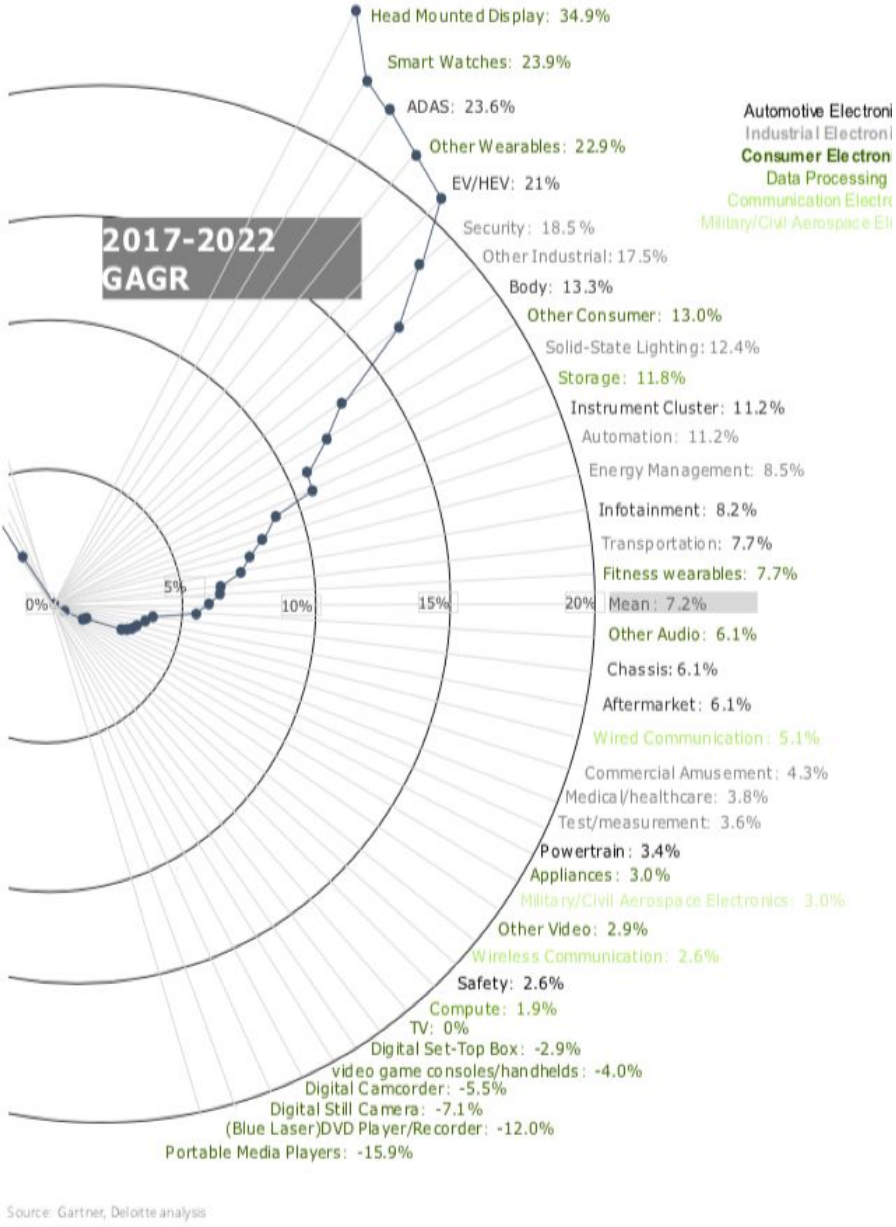
The future of automotive semiconductors

The automotive industry has come a long way in terms of providing factory-installed electronics meant for safety and comfort. Back in 2004, only a quarter of cars had airbags and less than 50% had factory-installed power seats. However, due to government regulation and customer demand, the adoption of safety-related electronics systems has exploded. Most of the automotive innovations taking place today arise from electronics rather than mechanics. The cost contribution of automotive electronics increased from around 20% in 2007 to about 40% in 2017.

The cost of semiconductor content, i.e. the components that make up electronic systems, has grown from USD312 per car in 2013 to around USD400 today. Automotive semiconductor vendors are benefiting from a

surge in demand for various semiconductor devices in cars, such as MCUs, sensors, memory and more. By 2022, the figure is expected to reach close to USD600 per car.

Figure: Semiconductor revenue growth by electronic equipment type (2017- 2022)



Source: Gartner, Deloitte analysis

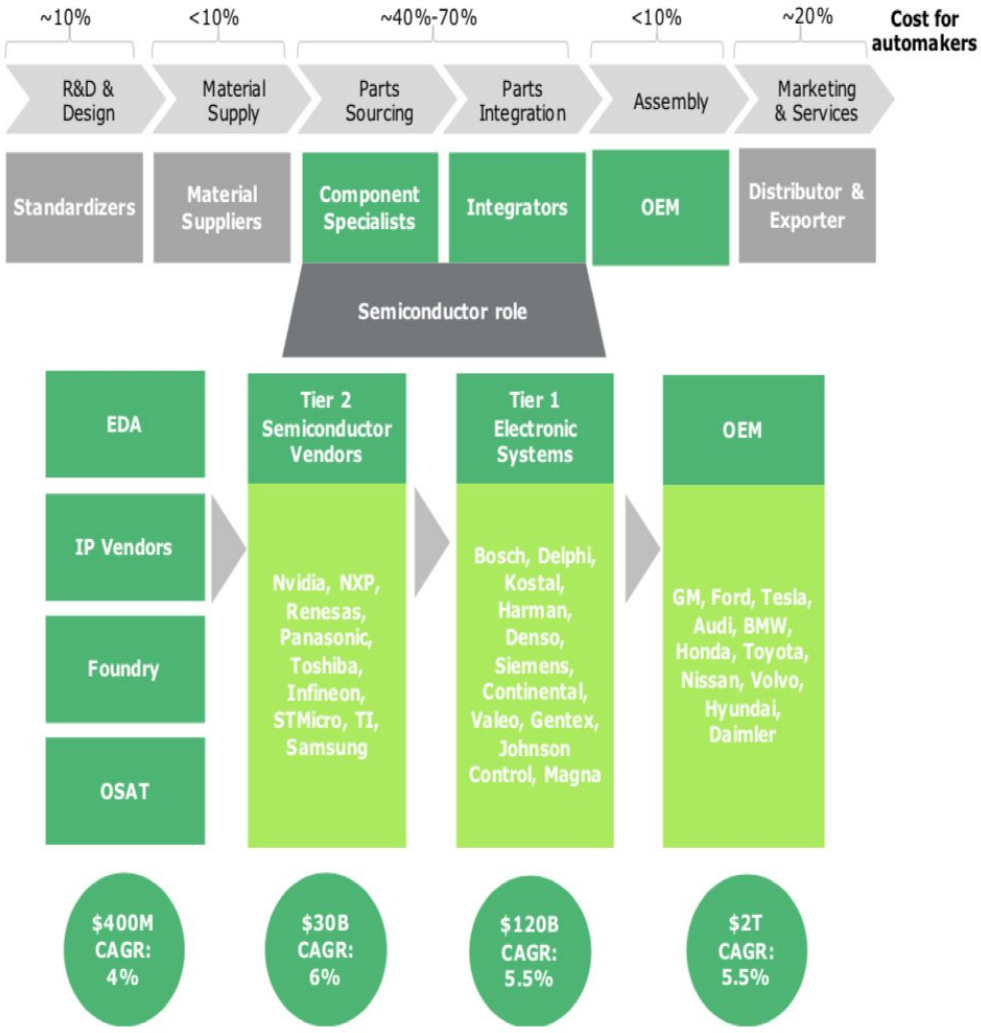
Semiconductor vendors play a critical role in the automotive industry supply chain. In the classic automotive ecosystem, semiconductor vendors sell to Tier 1 electronic systems vendors, which then integrate technology into modules and send these to the automaker (OEM) for assembly. In recent years, the automotive industry has been undergoing massive transformations that will re-invent the entire ecosystem for years to come.

Advances in technology such as AI, electric vehicles (EVs), autonomous driving, energy storage, and cyber security; social awareness of topics such as safety and ride-sharing; environmental concerns like pollution; and economic considerations including infrastructure spending and growth in Asian markets are all set to reshape the automotive industry.

Automation, electrification, connectivity and security

Four mega trends will result in more semiconductor content being added to automotive electronics and subsystems in the next decade.

Figure: Role of semiconductors in the automotive ecosystem



Source: Cadence, IHS, Deloitte analysis

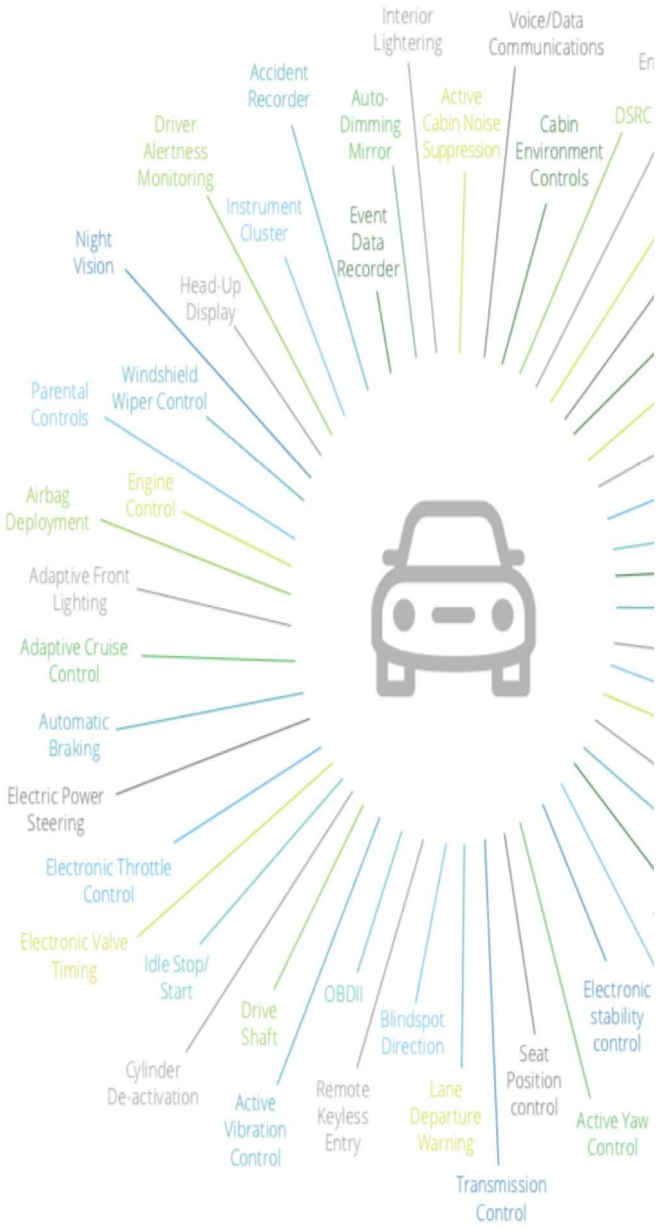
1. Automation

Widely considered as the ultimate goal for the future of mobility. Automakers and Tier-1 suppliers, as well as technology providers (e.g. semiconductor vendors) and smart mobility companies (e.g. ride-sharing companies) not traditionally involved in the automotive industry, are all racing to develop and invest in related technologies. Semiconductor vendors in particular are actively developing a wide-range of microchips, fusion and system-on-a-chip devices incorporating AI and machine learning technologies.

Safety is a key selling point for autonomous vehicles. However, getting to full autonomy (Level 5), requires advancements in technologies such as ADAS safety systems that can reduce the number of traffic accidents,

including electronic stability control, lane departure warning, anti-lock brakes, adaptive cruise control and traction control. All of these require complex electronic components that include high-speed processors, memory, controllers, sensors and data links to ensure the reliability and safety of a vehicle. For example, sensors will play a critical role in the shift to autonomous driving. More sensors are required to enable autonomous capabilities. The number of sensors used in vehicles will increase as autonomy levels rise. At Level 4, the number of sensors could reach 29. These features will not be limited to high-end cars, but will move into mid- range and economy models where volume movement is going to be much higher in the next few years.

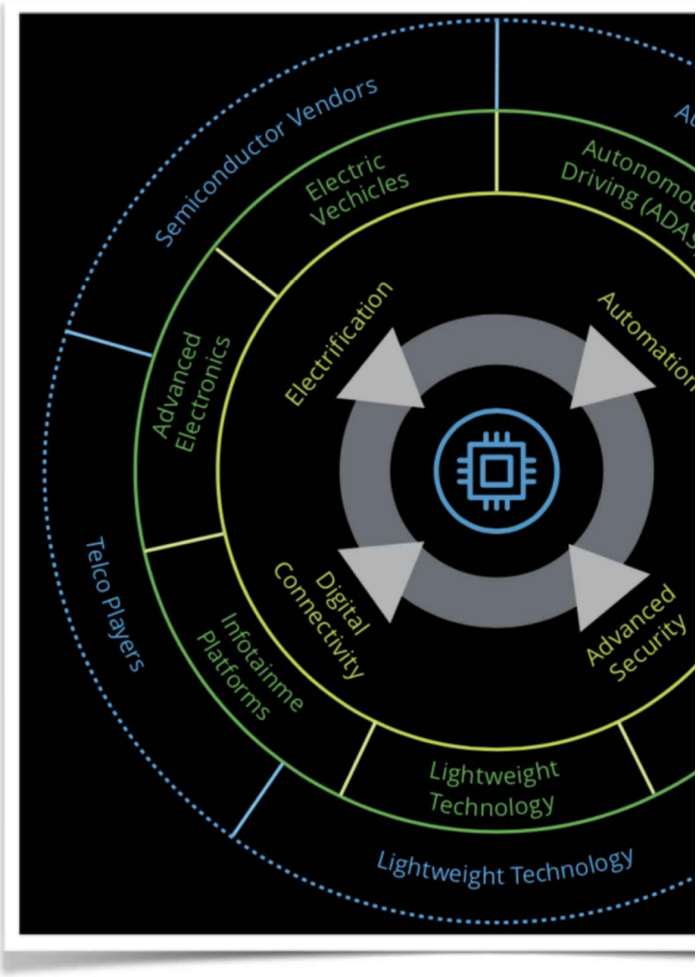
Figure: Factory-installed electronics



2. Electrification

The need for cars to be more fuel-efficient, and the impetus of government regulation to lower emissions, are driving up semiconductor demand for both traditional vehicles and EVs/hybrid electric vehicles (HEVs). In today's traditional internal combustion (ICE) engines, there is still huge potential to lower CO2 emissions. Many sensors and controls are required to run an engine efficiently and significant improvements can still be achieved. The Chinese government, for example, will introduce the new "6A" emission standard by 2020 to further lower vehicle emissions.

At the same time, EV/HEV advances require progress on the electrification of power trains. Governments in many countries are beginning to ban, or in the process of banning, ICE-based cars completely. China is targeting increased EV production by automakers (10% of total production from 2019). Many global automakers have also set goals to have EVs account for 15%-25% of their sales within 10 years, thereby bringing EVs to the masses. As major OEMs pursue their EV goals, growth of the semiconductor industry will increase proportionally. Thus, conditions are ripe for innovation in electronic powertrain technologies that will be used to reduce total emissions, thereby accelerating more demand for semiconductors.



3. Digital Connectivity

Then there is digital connectivity— advanced vehicle connectivity (V2I, V2V, in-vehicle)—that connects both the inside and outside of a car and makes it a part of the Internet of Things. Automakers have begun to provide operating systems (OS) to act as platforms for potential app stores, as well as developed tailored apps, services and media content. Digital technology players are adapting

their mobile platforms to cars and developing in-car entertainment platforms. Some media-streaming services and device manufacturers have formed partnerships with automotive OEMs. Digital tech players

especially have an advantage in this area, due to their core capabilities and aggressive capital investment. From a consumer's perspective, in- car digital connectivity and content will become the norm, particularly with Asian customers who consider entertainment a basic automotive function with flawless integration

of their personal mobile devices. Connectivity is not just entertainment; vehicle-to-vehicle communication isa critical technology for autonomous cars to realize driverless technology and avoid accidents. It is expected that by 2023 over 90% of vehicles produced will be connected.

4. Security

As vehicles become more connected, hardware and software platforms will be increasingly exposed to hacking risks. A failure in one vehicle component could have an avalanche effect. For example, if vehicle communications were attacked maliciously, advanced vehicle systems would not be able to receive vital situational awareness information and integrated vehicle security systems (control braking, acceleration and crash avoidance, etc.) would fail to react. Thus, automotive electronics vendors today are more focused than ever on the safety and reliability of vehicles.

Two levels of protection are being considered to deter any potential threats. The first is developing policy and establishing cybersecurity standards, so that manufacturers can follow a rigorous process for establishing the safety of connected vehicles. Standards alone may not be sufficient, however, as automakers and technology players will need to build components that are highly

secured with no introduced back doors or Trojans, assess vulnerabilities in software and firmware, provide over-the-air (OTA) updates and have communications links.

Future states of mobility will coexist

We envision that these transformations will create four co-existing states in future mobility, where vehicle ownership diverges between the shared and the personal, while vehicle control continuously moves towards complete automation.

Components of Connected Car

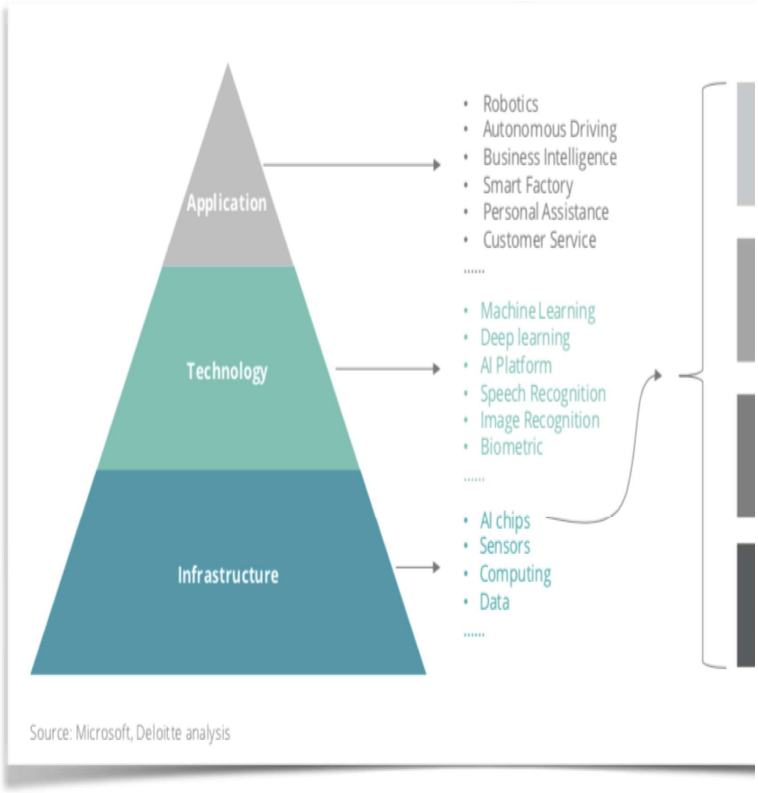
The race is on for AI chips

The race for AI chip domination

The artificial intelligence framework can be broadly characterized into three layers.
The infrastructure layer includes the core AI chips and big data that support the sensing and cognitive computational capabilities of the technology layer. The application level sits at the apex, providing services such as autonomous driving, smart robotics, smart security and virtual assistance. AI chips form the heart of the AI technology chain and are central to the processing of AI algorithms, particularly for deep neural networks (DNN).

"Depth" refers to the layers and number of nodes in a neural network model. Over the years, the complexity between layers and the number of nodes have grown exponentially.
This presents a significant challenge for computation. Traditional central processing units (CPUs) excel at general workloads, particularly if they are rules-based. However, CPUs can no longer keep up with the parallelism required of AI algorithms.

There are two major ways to address the parallelism issue. One is to add a dedicated accelerator based on existing computational architecture. The other is to re-develop completely to create a new architecture that simulates the neural networks of human brains. The latter approach is still in the early phase of development and unsuitable for commercial rollout. The addition of AI accelerators will therefore be the primary method. Numerous types of AI chips are available for acceleration: mainstream ones including GPUs, field-programmable gate arrays (FPGA) and application specific integrated circuits (ASIC), with variations including TPU, NPU, VPU and BPU, etc. Each has its own strengths and weakness.



GPUs used to process graphic intensive tasks such as games are built with parallelism in mind. GPUs have very high performance suitable for deep learning AI algorithms that require a lot of parallelism. This new role makes GPUs a great choice for AI hardware. GPUs are now widely used in cloud and data centers for AI training. They are also used in the automotive and security sectors. The GPU is currently the most widely used, most flexible AI chip available.

FPGAs, meanwhile, are programmable arrays suitable for clients that want to reprogram based on their own requirements. FPGAs are characterized by a faster development cycle (versus ASIC) and low power requirements (compared to GPUs). But, their flexibility makes their cost relatively high. FPGAs can be seen as a good compromise between efficiency.

Efficiency and flexibility, especially when an AI algorithm has not been finalized. This allows vendors to optimize custom chips for their applications while avoiding the cost and potential technology obsolescence of the ASIC approach.

ASIC AI chips, on the other hand, have dedicated architecture for AI applications. ASIC-based AI chips have many variations, including TPU, NPU, VPU and BPU, etc. These are all aimed at diverse, computer-intensive, rules-based workloads with high efficiency and performance and the flexibility of a CPU. Typically, ASIC AI chips have higher efficiency, a smaller die size, as well as lower power consumption than GPUs and FPGAs. But, ASIC chips' development cycle is longer and less flexible, which has contributed to its slow commercial adoption.

There are two distinct AI deployments in deep learning: training and inference. AI utilizes big data as a foundation to "train" neural network models, using training datasets to obtain these newly trained models.

A newly trained model is then armed with new capability to "infer" from new data sets to reach a conclusion.

The training phase requires a tremendous amount of computational power because it requires the application of a huge data set to a neural network model. This requires high-end servers that have advanced paralleled performance to be able to process large, diverse and highly parallel datasets.

Therefore, this phase is typically done via hardware in the cloud. The inference phase, on the other hand, can be handled either in the cloud or on devices (products) at the edge. Compared to training chips, inference chips require more thoughtful consideration of power usage, latency and cost.

Innovation in AI chips has just begun, with vendors taking different approaches to chip acceleration. Google, for example, has taken the ASIC path, whereas Microsoft has demonstrated that comparable, and sometimes even better results can be achieved using an FPGA. Meanwhile, Xilinx, Baidu and Amazon are all working to lower the traditional barriers to FPGA adoption.

AI chips to enjoy explosive growth

The AI chip market is expected to account for over 12% of the total AI market by 2022, with a CAGR of 54%. The Americas is expected to lead the market, followed by EMEA and then APAC. The Americas overall will dominate the market throughout 2022.

Cloud-based AI chips the most promising segment

The AI chip market can be split into two categories based on deployment methods: cloud-based and network edge.

The cloud is the biggest market for AI chips, as their adoption in data centers continues to increase, enhancing efficiency, reducing operational cost and improving infrastructure management. In particular, the AI training market will reach almost USD17 billion, with inference chips on the cloud accounting for USD7 billion. By product type, GPUs have become the mainstream choice for AI chips and have the largest share, accounting for over 30% of the market.

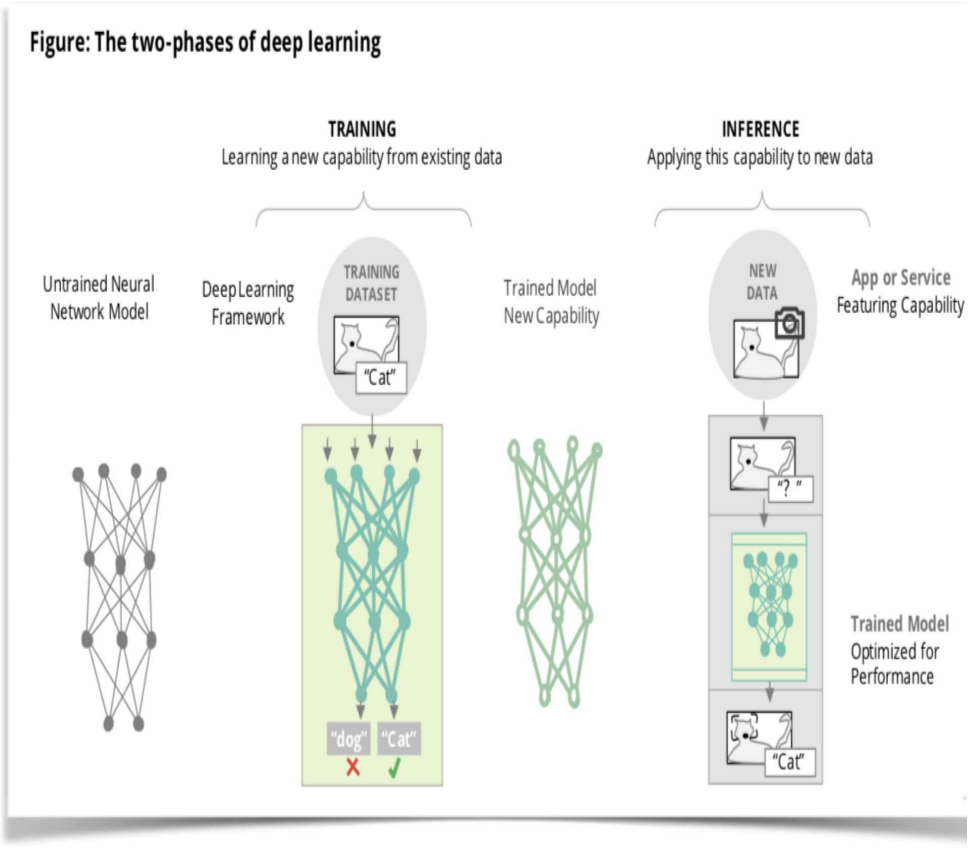
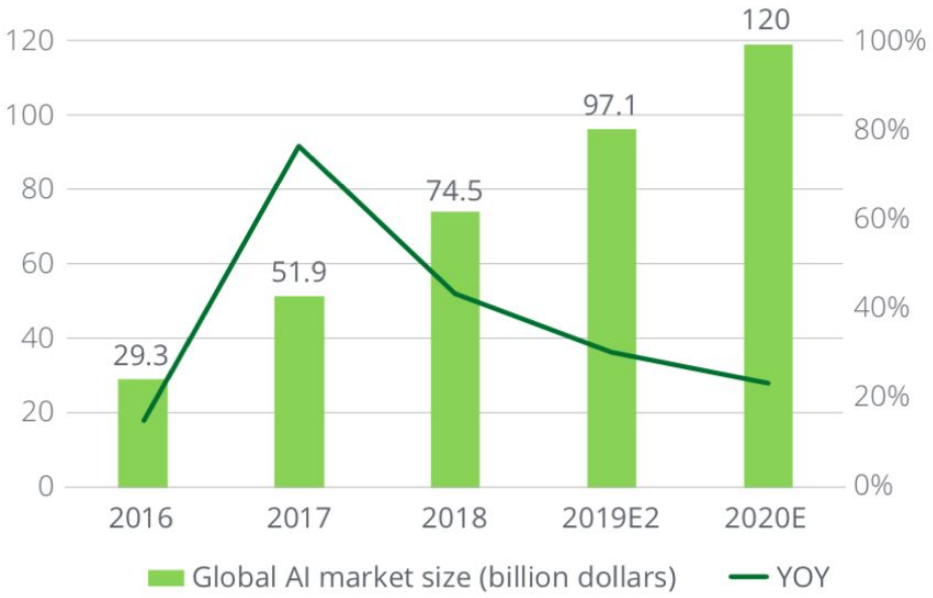


Figure: The global AI and AI chip market (2022)



Network edge AI chips are emerging
AI chip deployment is not limited to the cloud, but can also be seen in a wide variety of network edge devices such as smartphones, autonomous vehicles and security cameras. Most AI chips at the edge are inference chips, and they are becoming increasingly specialized. The AI inference chip market is expected to grow at a CAGR of 40% and reach USD2 billion by 2022.

AI chips drive smartphone ASP

AI chip vendors could benefit from the rising cost of their products. For example, Apple's A11 chip cost has risen to USD27.50. The rise in cost of AI chips will in turn increase prices of smartphones, providing smartphone manufactures with increased revenue. AI chips have also moved down from high-end phones to mid-range ones, potentially bringing even more revenue to smartphone vendors.

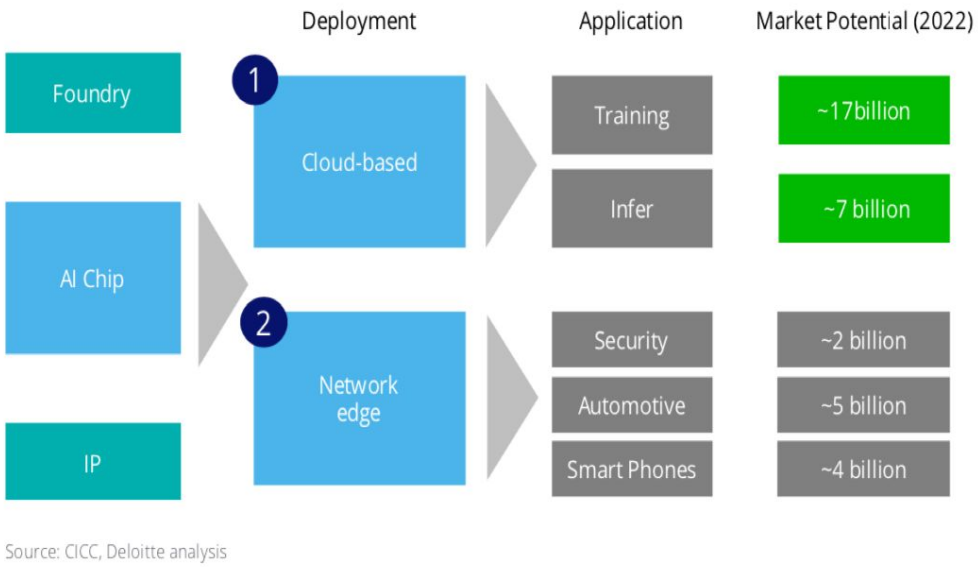
Inference AI chips in smartphones are now part of a three-way race between smartphone manufactures like Apple, Samsung and Huawei; independent chip providers such as Qualcomm and MediaTek; and IP license providers including ARM and Synopsys. AI chips from smartphone manufactures are typically optimized for their own phones with the goal of improving performance and user experience. However, independent chip providers could come out with better chip specifications to compete for the rest of the market.

Autonomous driving the ideal application for AI chips Autonomous driving is not only a complex application scenario for artificial intelligence but also an important one. It is expected be a major driver for AI inference chips, with an estimated market value of USD5 billion and a CAGR of 40%.

Sensing, modelling and decision making are the three-step process normally required for autonomous driving, and inference chips are involved every step of the way. Whether they are used for environment sensing or obstacle avoidance, autonomous driving has high requirements for the computational power of AI chips.

Owning to limitations in latency, computation in autonomous driving should ideally be done on the edge rather than in the cloud because decisions need to be made in near real-time. According to Toyota, computational power of 12 tera operations per second (TOPS) is required to realize L5 autonomous driving, but most chips today are only capable of supporting 2-3 TOPS. There is a clear urgency for AI chips to migrate to the edge instead of doing the heavy lifting in the cloud.

OEMs are testing chips from vendors to identify the most suitable candidates. Large OEMs have prefer constructing their own autonomous driving platforms and purchasing AI chips separately, whereas newer OEMs normally prefer buying complete autonomous driving platforms.



Source: CICC, Deloitte analysis

Smart surveillance systems have high demand

Surveillance systems are getting smarter thanks to AI. The surveillance system industry has gone through three phase of transformation in the past 10 years. The first wave was the "high definition" phase, where a system is capable of recording ultra-clear videos. The second wave was the "networking" phase, where networking and interconnection capabilities are added to the system.

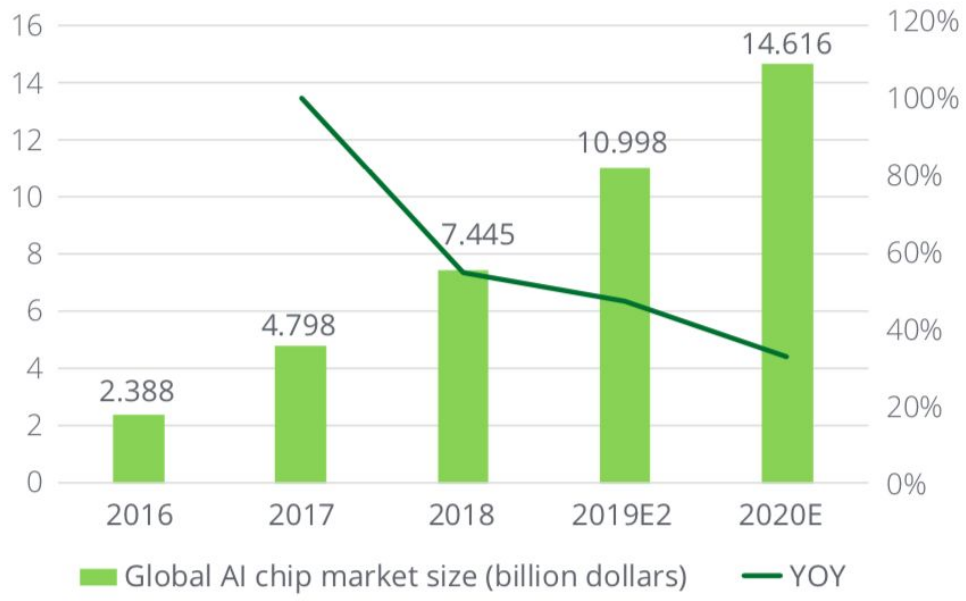
The addition of AI can be seen as the "third wave" of transformation. AI inference chips are now added to cameras at the edge, allowing real- time processing of video data. This saves storage space on the cloud and increases the performance of surveillance systems as massive amounts of data are generated on the edge each day.

China now the hotspot for AI chips

AI chip funding activity in China has been active and M&A is also on the rise. One example is the acquisition
of DeePhi, a start-up with industry- leading capabilities in machine learning, deep compression, pruning, and system-level optimization for neural networks, by global giant Xilinx. Tech giants are also getting entering the field of play, led by Alibaba, Baidu and Huawei. In particular, Huawei

has lit up AI chip competition in the smartphone sector. Some Bitcoin mining equipment manufacturers are also getting into the AI optimization game.

AI companies in China are generally swift at identifying viable business applications for AI, especially business model innovation and rapid implementation. However, original



AI model creation capabilities are a rarity among Chinese players, with most domestic research in AI focused on tweaking and perfecting existing models, rather than creating an original and systematic AI framework. In addition, training devoted to AI is also limited in China compared to countries such as the US.

Navigating the AI scene

The rise of artificial intelligence has certainly created new opportunities in semiconductor devices, particularly for AI chips. Semiconductor companies already in or planning to enter AI systems should adhere to the following key observations to stay competitive.

Specialization is key to AI chips: In future, AI chip companies should no longer be content just to be hardware companies, but possess a deep understanding of the requirement of their customers to create suitable products. Customers today are not just looking for a general-purpose chip with some added AI capability; they are looking to see whether it can satisfy their business requirements at a reasonable cost. They should balance

power, performance and cost. Computational density (computational power per unit of power consumed) will become a core competitiveness for AI chip vendors.

Moving from the cloud to the edge: Opportunities have begun to pop up at the network edge and many large players are moving from the cloud to the edge to offer comprehensive AI solutions that span the spectrum, from training to inferencing workloads. It is worth noting that most AI systems today run on von Neumann architecture, in which processing and memory are separate. This has led to AI becoming power hungry and left neural networks stuck in the cloud. Efforts are being made to create a new architecture that allows more tightly coupled processors and memory, which improve performance and energy efficiency. The idea is to add new functions to memory that will make devices smarter without replacing the processor. The semiconductor industry should embrace such designs so AI can be brought out of the cloud and onto the edge.

Select the appropriate semiconductor process technology: Unlike CPUs, which need the most advanced processing technology available according to Moore's law, it is not always necessary for AI chips to be designed on the latest process technology due to

AI's use of parallel processing. For example, 40nm and 28nm processes are sufficient to provide 1 TOPS of computational power. In addition, older-generation processes have access to mature toolsets and building blocks. Many large foundries offer a wide range of advanced process technologies, ranging from 28 nm all the way to 7 nm, depending on their mix of performance and power capability. For semiconductor vendors, selection of the appropriate semiconductor process technology should ideally be based on criteria such as computational capability and power consumption, as well as form factor.

Software tool support is essential: The amount of support semiconductor companies have
for standard open-source software frameworks is key to winning the AI race, particularly for challengers trying to catch up with leaders that already support literally all deep learning software and tools for their semiconductor chips. To be a viable contender in this market, semiconductor vendors should at a minimum support major open source software frameworks such as TensorFlow, Caffe2, Theano, CNTK, MXNet and Torch. Tools to help developers build applications are also required. Semiconductor vendors will need to invest in software and collaborate with software developers to access their AI device architecture. The number of software frameworks for processing neural networks is growing. Many will be developed and released over the next few years, so there is still room for new entrants to grow.

Look for opportunities beyond
AI chips: Artificial intelligence does not rely on AI chips alone to achieve its processing power. Memory is also an important component in the advancement of AI, where high throughput parallel processing places multiple strains on data bandwidth in memory systems. The demand for AI system memory will create opportunities for memory vendors. In addition, as AI systems scale up, the performance of interconnects between subsystems and devices will become a bottleneck. Thus, opportunities also exist for semiconductor vendors to create high speed interconnects to meet the demand of high volume data flowing between systems. Further, AI chips today can contain multiple processors to achieve maximum parallelism, resulting in a very large die size.

This presents a great challenge for thermal and high voltage power management in which custom cooling solution may be required. This creates opportunities for packaging vendors to come up with products that have thinner form factor and less thermal dissipation for a more cost-effective solution.

Mergers and acquisitions (M&A)

M&A activity in semiconductors is already past its peak and specialized verticals such as automotive, AI and network/data centers are becoming the most sought after emerging verticals. Japan and Korea have been actively seeking to revive their semiconductor industriesvia acquisitions of mid-sized companies in the US and Europe,as well as cooperation with China.

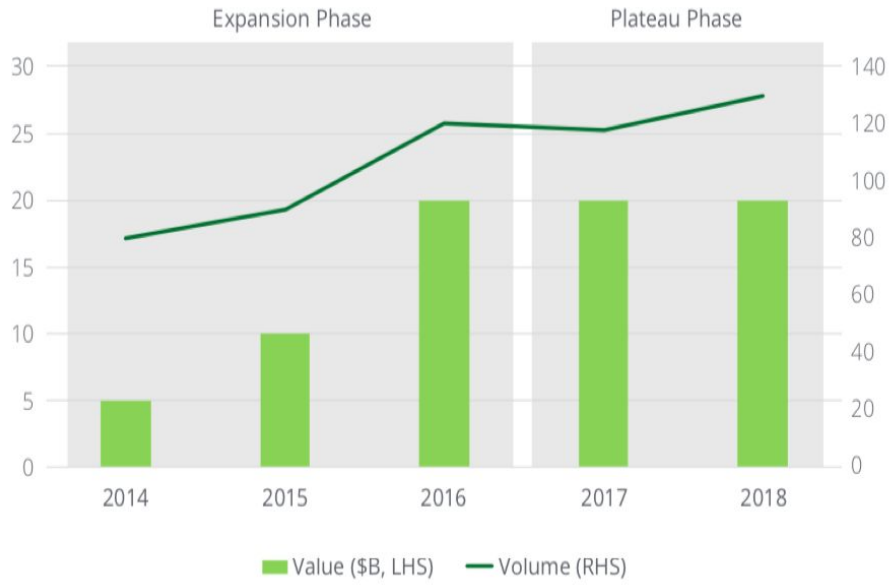
At the same time, disputes over intellectual property and national security issues will dampen China's ambition to go global. The tightening of Chinese outbound investment in high-tech companies from the US will become the new norm, shrinking the overall size of the global M&A market. Regardless, semiconductor conglomerates are always on the lookout for potential targets in various verticals that have high market share and profit.

M&A enters plateau phase

Global semiconductor M&A transactions peaked at over USD120 billion in 2016. In 2017, the value of M&A in the semiconductor industry fell sharply. In addition to fewer M&A targets due to previous transactions, tightened regulatory reviews by Europe and the US were an important factor. M&A transaction value rose again in 2018 due to value per deal. For example, US-based Broadcom acquired CA Technology for USD17.99 billion.

In East Asia (China, Japan, South Korea and Taiwan), M&A volume showed rapid growth between 2014 and 2015, amounting to over USD22 billion. However, after several years of rapid expansion, the pace stalled somewhat in 2017 and 2018. In 2017, the volume of semiconductor M&A in East Asia declined 1%, while value grew a modest of 2%.

Figure: East Asia (China, Korea, Japan and Taiwan) M&A transactions (2014-2018)



Government policy has been the largest contributor to the rapid development in China over the past five years. China today is the largest importer of semiconductor chips globally and the government's overall strategy is to reduce reliance on foreign imports and build up its domestic semiconductor base, which has fueled Chinese companies' entrance into the industry and acquisition of advanced technologies.

In domestic M&A, Mainland China is undoubtedly the most active region in East Asia. Its M&A volume had a compound growth rate of 24% from 2014 to 2018. For example, in 2018, Alibaba acquired Hangzhou C·SKY. Before this, Alibaba had invested in five chip companies: Cambrian, Barefoot Networks, Deephi Tech, Kneron and ASR.

M&A activity in Japan, South Korea, and Taiwan was relatively quiet compared to China. The main motivations for deals there are strengthening market position and expanding market share, as well as searching for emerging applications.

Outbound M&A mixed

Overall, volumes of cross border M&A from East Asia declined after 2016, particularly as the US strengthened its investigations of Chinese companies seeking leading-edge technologies.

In 2017, the White House published the report, Ensuring Long-Term US Leadership in Semiconductors, which sets out the perceived threat posed by China's semiconductor policy to the United States and suggests the US government take steps to prohibit or heavily restrict Chinese acquisition, as well as tighten rules that restrict the flow of critical semiconductor intellectual property. Yet, despite increasing government reviews of M&A, North America and Europe are still the main destinations for East Asian semiconductor companies.

The motivations for M&A are clear

Semiconductor companies today are motivated to conduct domestic and cross-border M&A primarily for four reasons: to acquire advanced technology; strengthen market position and expand market share; search for cutting-edge applications; and expand their industry supply chains

Acquiring advanced technology:

The semiconductor industry in
China relies heavily on imports. In 2018, there have been some urgent moves from Chinese tech players.
For instance, Chinese semiconductor cleaning equipment company NAURA acquired Akrion, a semiconductor wafer cleaning equipment company in Pennsylvania, to expand its business into silicon wafer fabrication, MEMS and packaging, becoming the first case approved by the Committee
on Foreign Investment in the United States (CFIUS) since the Trump administration took office.

Despite possessing more advanced semiconductor technology, Japan, South Korea and Taiwan are still seeking semiconductor-related technologies through M&A. Taiwan-based company United Microelectronics acquired a 84% stake in Japan-based wafer foundry company Mie Fujitsu Semiconductor for USD519m in June 2018 to enable UMC to leverage its IC production experience. Meanwhile Taiwan Semiconductor Manufacturing Company acquired US-based ON Semiconductor for USD6M to expand its semiconductor application portfolio and strengthen its core business.

Strengthening market position:

By acquiring competitors, enterprises play a synergistic role to increase market share and enhance profitability. In 2018, Shanghai Will

Semiconductor acquired a 85% stake in Beijing SuperPix Micro Technology and a 96% stake in Beijing OmniVision Technologies for USD2.18bn to

take advantage of the high-end technics of OmniVision and cost control capabilities of SuperPix. M&A also paves a path to quick market entry, particularly overseas. South Korean foundry SK Hynix acquired

a 50% stake in Chinese foundry company Haejin Semiconductor (Wuxi) by investing USD75m as
a strategy to expand its foundry business. China-based company Huada Semiconductor has acquired Canadian Solantro Semiconductor, which designs integrated circuits, to establish and grow its presence in Ottawa.

Accessing emerging sectors: The rapid development of emerging technologies such as artificial intelligence and autonomous driving has greatly stimulated demand for semiconductor chips. Chip companies are now expanding their business areas to emerging sectors through M&A. For instance, Samsung Electronics has acquired Haman, one of the largest suppliers of connected, intelligent automotive component globally. In 2018, Japan- based developer and manufacturer of semiconductors Renesasa Electronics acquired US-based company Integrated Device Technology (IDT) to enhance its competence in self-driving car technology.

Expanding industry supply chain:

The semiconductor industry chain includes design, manufacturing, packaging and testing from upstream to downstream. By entering other parts of the value chain, incumbents not only create new revenue streams, but also create synergies. In 2018, Ingenic Semiconductor, the leading embedded CPU chip and solutions provider in China, acquired a stake in Beijing Xicheng Semiconductor, which will enable Ingenic to expand into the high-end memory chip business.

Look out for M&A risks

Despite the many benefits of M&A, a host of issues can arise pre and post-merger, including mistakes in judging the target, failure to conduct detailed due diligence and poor implementation.

Risks Related to M&A Target Screening and Valuation
The Chinese technology industry faces various political and legal risks in overseas M&A. Governments in
the US and Europe have very tight restrictions on foreign acquisitions

or investments, especially in semiconductors as a high-tech industry. It will be difficult for Chinese companies to acquire high-tech companies with the advantage of
high technology and high commercial value, which can increase the difficulty of selecting M&A targets. In addition, although Chinese enterprises can obtain intangible assets (such as technology and brand) and advance their industry level by acquiring foreign enterprises, the premium

paid is generally high, which brings substantial operational and financial risks to Chinese enterprises. High financial leverage is the most significant characteristic of overseas M&A for Chinese enterprises. And high leverage inevitably brings high risks. If M&A fails or companies fail to integrate, leading to losses, M&A companies will face great financial risks.

Risks Related to Financial Information and Due Diligence Compared with domestic M&A projects, overseas M&A projects have a different quality of financial information, interpretation, supply method and verification. Accordingly, due diligence procedures should be reasonably arranged to deal with these differences.

M&A involving foreign semiconductor companies needs to focus on the risks in shareholders' backgrounds:

1) Small and medium-sized enterprises managed by founders: these companies often do not pay enough attention to daily accounting, have relatively confused financial data, and do not employ well-known accounting firms to audit their financials. It is difficult to obtain financial data to conduct business analysis through written materials.

2) Private-equity fund management enterprises: Private-equity funds tend to plan business expansion in the early stage, and sell at better performance points. Therefore, financial data is detailed and comprehensive, corresponding written materials are available and financial data is highly authentic. However, good historical financial performance can often be caused by short-term incentives. Although current profits are high, the development prospects may be limited.

Risks Related to Overseas M&A and Integration
There are many challenges for cross- border mergers and acquisitions

in the process of transaction and integration, including the complexity of restructuring, lack of local integration resources and teams, management of external stakeholders and loss of talent, differences in management information systems, and differences in culture, salary and welfare systems. Specifically, these include:

Differences in culture and subsidy benefits systems: Different performance appraisal systems will have an impact on employee performance. Generally, the higher the degree of company localization, the lower the basic wage and the higher the sales commission; whereas the basic wages of foreign enterprises are generally higher and sales commission relatively low; these differences may cause inequalities in wages and subsidies in the integration of two enterprises, affecting the enthusiasm of employees.

Brain drain and management:

M&A can result in the loss of core managerial personnel, thus affecting the normal operations of a company's business. Core personnel include: people who master key technologies/ processes, those who master government and customer resources. Senior managers with multiple roles will have greater resistance to corporate restructuring. A company is likely to lay off employees after reorganization and its leadership responsibilities can change.

Complexity and chain reaction in restructuring: Foreign labor laws highly favor the employees' side; if restructuring could cause social instability, local governments might interfere with factory relocation/ restructuring plans.

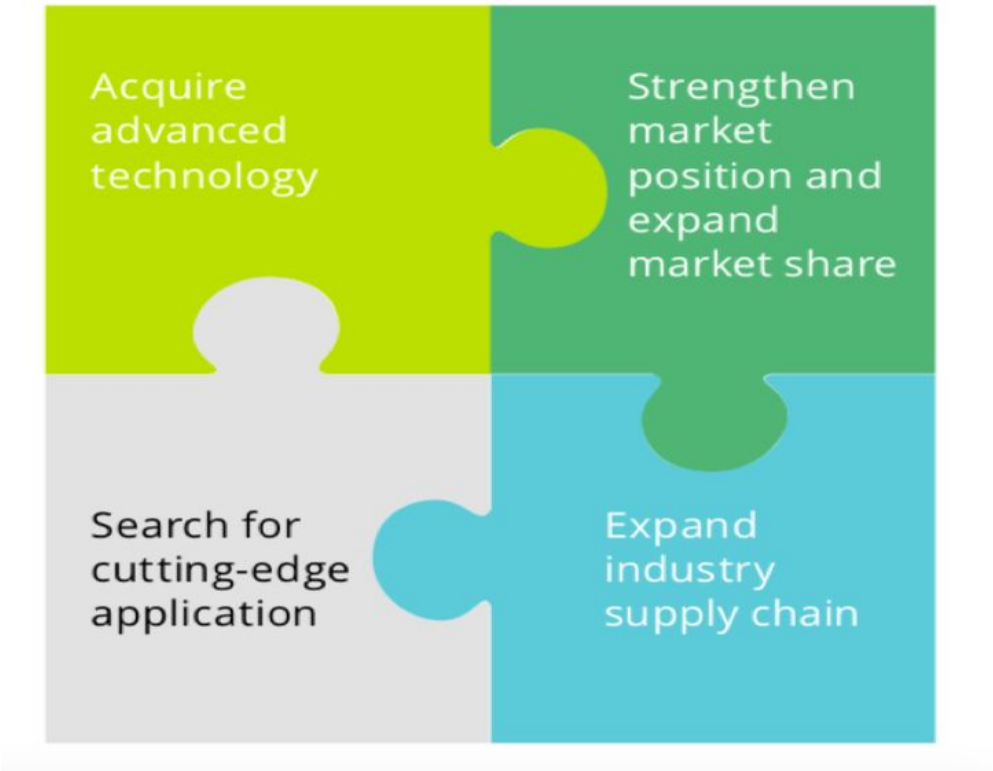
Lack of local project teams with the function of supervising the reorganization process: M&A and reorganization projects are typically headquarters-led, but a lack of local team participation can lead to local problems that cannot be submitted to a preparatory committee for resolution; a lack of local team leadership will reduce the effectiveness of the implementation of a reorganization plan. Language and cultural barriers can hinder project teams' ability to communicate effectively with local staff.

Low-efficiency in external stakeholder management: customers and suppliers may think restructuring will bring uncertainty to a company's business, and lose confidence in cooperation or confuse future partnerships; disruption of supply flow and customer losses may be difficult to reverse; competitors could seize the opportunity to compete for passenger flow during the restructuring run-in period.

Differences in management information systems: Most Chinese companies adopt a native enterprise resource planning (ERP) system, such as UFI, which will hinder information sharing with companies using Oracle/SAP ERP systems to a certain extent, resulting in some delays in information reception and operation.

Digitalization

Figure: Motivations for M&A in the semiconductor industry


Acquire advanced technology
Strengthen market position and expand market share
Search for cutting-edge application
Expand industry supply chain

Semiconductor companies tody must be more rapid and agile than ever to remain competitive. The commercialization of new technologies such as AI and big data is promoting the digital transformation of enterprises and the realization of intelligent production, intelligent management and intelligent sales.

By investing in digital infrastructure to increase productivity and develop new business channels, companies will have the opportunity to overcome development barriers and digitalization will provide new impetus for their development. Digital transformation has become the main strategy for many enterprises to meet the challenges they face. For example, the digital transformation of the retail industry has penetrated all areas of the value chainInvolving consumer-oriented demand forecasting, personalized marketing, purchasing experience and intelligent customer service. The main aim is to continuously improve efficiency and effectively attract consumers.

The foundations of digitalization are sound, as chip processing capacity, cloud service popularization, sensor and other hardware prices have

declined and computing power has improved a great deal. From the application perspective, technology companies have provided the market with various data analysis tools to improve data utilization rate, improve operational efficiency and reduce production costs.

Many semiconductor companies are already utilizing digital tools to gain competitive advantage throughout the product life cycle. For example, the application of AI and analytical tool applications in the semiconductor industry extends from design, manufacturing, packaging and testing all the way to management.

Artificial intelligence paves way for efficiency

AI technology will play an indispensable role in all aspects of semiconductor production and company operations. Massive amount of data is generated in the semiconductor manufacturing process and traditional data analysis methods can only utilize parts of the structured data for post- mortem analysis. But intelligent analytics based on AI can perform comprehensive real-time analysis of data sets to improve production and management efficiency.

Design: Artificial intelligence can alter the process of design. Each step in the semiconductor design produces a large number of parameters. Unlike traditional analysis tools, new analysis technology can help semiconductor designers comprehensively analyze all the data they obtain, and learn from experience, as well as analyze past data and extract relationships from the data and results. Whether it is high frequency or low- to medium- frequency data, data combination can be used to spot potential errors and increase yield, providing insights into newly generated data to make decisions or correct errors by simply changing a certain parameter. In addition, using data as a basis for decision-making can avoid communication barriers between design teams and process teams.

Manufacturing: In the manufacturing process, data generated by each process are shared, as well as directly analyze and report errors, thereby reducing manual inspections that may contain errors, and improving efficiency. An AI system can check data thousands of times in a minute, providing nearly 600 times the efficiency of staff. AI detection and maintenance system connections cover the entire process of production data, and can build real- time predictions about equipment failures, reducing losses caused by production interruptions.

Packaging and testing: The full use of data shortens testing time and accelerates time to market. Data integration and connectivity can greatly improve data utilization efficiency. On one hand, building a data exchange platform between semiconductor testing companies and component

suppliers can enable the causes of errors to be found in time, and on the other hand, it can reduce the number of malfunctioning chips. These platforms have reduced the number of malfunctioning chips by 50%.

Figure: Digital tools utilized by semiconductor companies

	Current situations	Improvement
Design	• Companies have to correct errors in physical designs (R&D) • Hard to find errors based on past experience (Upgrade)	• Correct design errors using virtual tools • Obtain data from device and tool to find out the factor creating mistakes and instruct next design
Manufacturing	• Data generated from each devices cannot be connected • Manual maintenance are required and cannot predict the machine failure	• Connect data from all equipment and create data set • Analyzing data set to predict the equipment failure in advance
Packaging and testing	• Consume a lot of time during testing	• Build plat platform for data sharing between testing companies and component suppliers • Reduce the time required to achieve acceptable shipping quality
management	• Pricing based on subjective opinions • Difficult to obtain data from other players along the supply chain • Hard to spot potential customer and provide service for them	• Data-based analysis could provide more accurate information for pricing • Create system to track all information related with chip and make it easier to find mistake • Spot potential customers that could contribute more on revenue

Source: Public information, Deloitte

Management: An AI customer service system starts with semantic understanding and problem identification derived from customer questions, searches for big data in the identified problems, analyzes the meaning of the problem, produces a knowledge map and performs answer matching and decision-making. An AI customer service system realizes 24-hour customer service online, answers questions at any time, improves customer satisfaction and saves the labor costs of semiconductor enterprises, as well as frees staff from boring and high-pressure work to do more valuable work.

Analytical tools to know customers better

Analytical tools are mainly being used in management, including decision-making and customer development. Data-driven decision support has undoubtedly become an important strategy to help semiconductor companies gain insights into potential customers, thereby making more rational decisions and reaching out to more customers. The application of data analysis tools includes information on changes in enterprises' daily income and the corresponding sales data. Combined with customer information and external auxiliary data, analytical tools can provide strategies and suggestions for the pricing of semiconductor products and form a smart pricing plan. A large amount of data is generated in interactions with customers. Through the continuous accumulation of customer demand data, a company can analyze and understand

preferences and needs in depth, as well as support precision marketing and large-scale personalized recommendations and services.

Master data management (MDM) is important

Master data management involves data collection, classification, management, cleaning and other areas within different organizations. It is the basis of AI data analysis and various data analysis tools.

The digitization of semiconductor companies is based on the use of data, as well as more refined management of enterprises' production and operations. Can the data generated by various sensors and smart devices be stored in the data set in time? How is the data classified? How can structured and unstructured data be managed and cleaned? How is the data from each area shared? MDM can solve all of these issues.

In the semiconductor design and manufacturing process, MDM can alsoprovide intelligent device data-to- data analysis. In the packaging and testing process, it can link the data of packaging and testing enterprises and component suppliers. In management processes, it can deal with business operations and financial data.

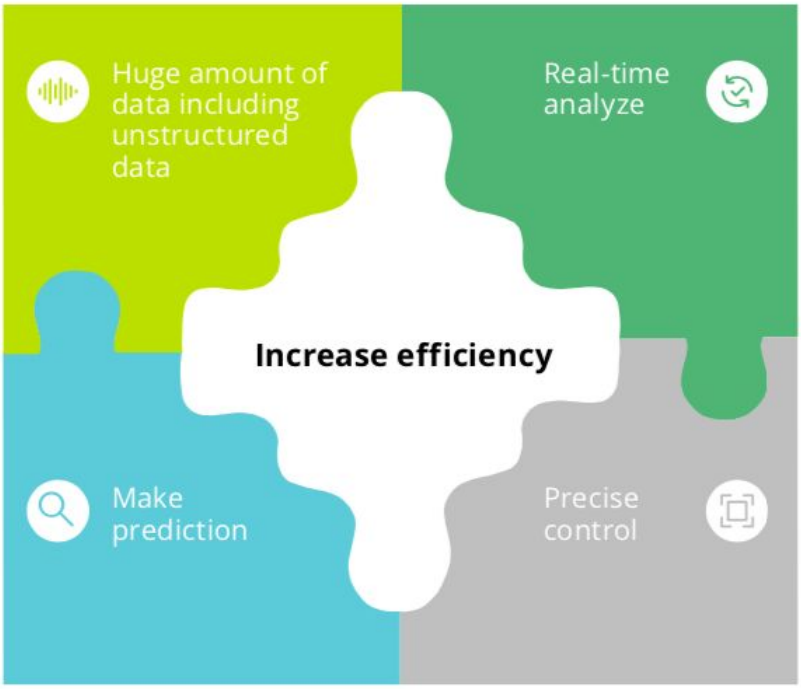
Indian Market Overview of Semiconductor Industries

The Indian semiconductor sector comprises pre-fabrication, fabrication and post-fabrication verticals. Despite the current slowdown in global markets, the Indian semiconductor market has shown sustained growth over the years. In 2007, the Indian Semiconductor Association (ISA)-Frost and Sullivan estimated the Indian semiconductor market* to be worth US$ 4.56 billion.This figure was rose to US$ 5.9 billion for 2008 at a compound annual growth rate (CAGR) of 13.4 per cent and, further on, to US$ 7.59 billion for 2010.

Introduction

The Indian semiconductor industry offers high growth potential areas as the industries which source semiconductors as inputs are themselves witnessing high demand. The end-use industries such as mobile devices, telecommunication equipment, information technology, office automation (IT & OA), industrial machinery, automobiles and several other industries have applications for computing in some form or other and thereby necessarily have growing demand for semiconductors. Now with the concept of Internet of Things (IoT) picking up momentum, the next generation of interconnected devices would further increase the demand for intelligent computing, thereby creating sustainable demand for semiconductors.

Figure: The benefits AI brings to semiconductor manufacturing



Source: Deloitte analysis

India has a very fast growing electronics system design manufacturing (ESDM) industry. India also has a strong design base with more than 120 units. According to the Department of Electronics and Information Technology (DeitY), nearly 2,000 chips are being designed every year in India and more than 20,000

engineers are working on various aspects of chip design and verification. The government has a strong focus in developing the ESDM ecosystem in India. Several subsidies and other incentives are on offer for setting up electronics manufacturing units in India.

Market size

According to a study by The Associated Chambers of Commerce of India (ASSOCHAM) and EY, the Indian electronics and hardware industry is expected to reach US$ 112-130 billion by 2018 as electronics and hardware manufacturers are looking to increase their manufacturing base in India to cater to the domestic market as well as the Middle East, Africa and SAARC countries.

According to the India Electronics & Semiconductor Association, the Indian Electronic System Design and Manufacturing (ESDM) market will grow from US$ 76 billion in 2013 to US$ 400 billion by 2020. Consumption of semiconductors, in the meantime, has also steadily climbed. According to a report by NOVONOUS, the semiconductor industry is estimated to grow from US$ 10.02 billion in 2013 to US$ 52.58 billion in 2020 at a Compound Annual Growth Rate (CAGR) of 26.72 per cent.

The research report expects that mobile devices are expected to grow at a high CAGR of 33.4 per cent between 2013 and 2020. Consequently the share of mobile devices in semiconductor revenue is expected to grow from 35.4 per cent in 2013 to 50.7 per cent in 2020. Further, the telecommunication segment is also expected to grow at a high CAGR of 26.8 per cent between 2013 and 2020. The IT&OA segment is estimated to grow at a CAGR of 18.2 per cent over the next seven years. Although consumer electronics segment is expected to grow at a CAGR of 18.8 per cent, its contribution to the total semiconductor revenue is expected to lower to 3.5 per cent in 2020 from 5.6 per cent in 2013. Automotive electronics segment is expected to grow at a fast clip of 30.5 per cent CAGR from 2013 to 2020. Consequently, its revenue contribution is set to rise to 3.9 per cent in 2020 from 3.2 per cent in 2013.

Investments

Mr Ravi Shankar Prasad, Union Minister of Information Technology, announced that the Foreign Direct Investment (FDI) in electronic manufacturing has reached an all-time high of Rs 123,000 crore (US$ 18.34 billion) in 2016 from around Rs 11,000 crore (US$ 1.64 billion) in 2014, primarily due to government reforms and its Make in India initiative.

The Government of India has allowed 100 per cent Foreign Direct Investment (FDI) under the automatic route in Electronics Systems Design & Manufacturing sector. According to the data released by the Department of Industrial Policy and Promotion (DIPP), the electronics sector attracted foreign direct investment (FDI) worth US$ 1.70 billion between April 2000 and December 2016.

Some of the notable developments in this sector are as follows:

- Panasonic Corporation, the Japan-based electronics company, plans to set up a new plant at Jhajjar in Haryana, which will manufacture refrigerators for the Indian market, along with setting up a research and development (R&D) center for appliances consisting of two technical divisions to strengthen the product development in the country.

- Samsung India Electronics Ltd has signed a deal to lease 100,000 square feet (sqft) of space at Oberoi Realty Ltd’s commercial property Commerz II in Goregaon suburb of Mumbai, for setting up its new corporate office.

- Next Orbit Ventures, a growth-stage investor, plans to invest US$ 100 million in Gujarat-based semiconductor fabrication project, through its fund focused on Electronic System Design and Manufacturing (ESDM) sector.

- India's first Centre of Excellence for Internet of Things (CoE-IoT) has been launched in Bengaluru with five start-ups, which will provide demonstration and concept labs for building IoT solutions for applications like agriculture, automobile, telecommunications, healthcare and consumer goods.

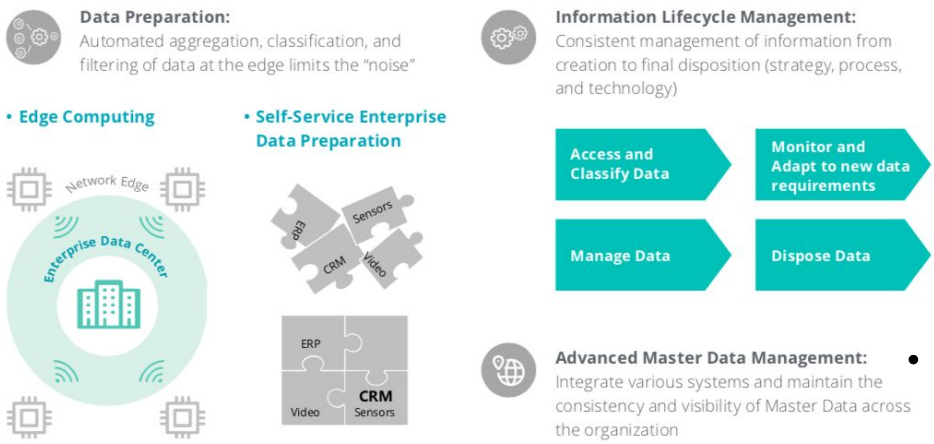
- Dow Corning, one of the leading global players in silicones, silicon-based technology and innovation, opened its Sahayog Building Solutions Centre in New Delhi, which will provide project support,

technical training and skill-building workshop to construction industry professionals.

- The Department of Electronics and Information Technology (DeitY) has approved proposals worth Rs 6,155 crore (US$ 917.8 million) under the Modified Special Incentive Package Scheme (M-SIPS), which aims to provide financial incentives to private companies for setting up electronics manufacturing units.

- Department of Electronics & Information Technology and M/s Canbank Venture Capital Fund Ltd plan to launch an Electronics Development Fund (EDF), which will be a 'Fund of Funds' to invest in 'Daughter Funds' which would provide risk capital to companies developing new technologies in the area of electronics, nano-electronics and Information Technology (IT).

Figure: Master data management



- Infineon Technologies, a German semiconductor firm has partnered with National Skill Development Corporation (NSDC) to impart training to youth on semiconductor or chip technology, aimed at boosting the electronic manufacturing ecosystem in India.

- US-based semiconductor company Freescale which has R&D facility in India, said that it is enabling its partners to bring smart products to facilitate the government's Rs 1.13 trillion (US$ 16.85 billion) Digital India initiative.

- Aricent, a US-based product engineering firm has acquired Bengaluru-based chip design services company SmartPlay for Rs 1,100 crore (US$ 163.06 million), making it one of the biggest acquisitions in the semiconductor space in India

- Invecas Technologies Pvt. Ltd, a startup working on outsourced chip design plans to invest US$15-20 million over the next couple of years

in setting up design centers in Hyderabad and Bengaluru.

- IESA has signed a MoU with Singapore Semiconductor Industry Association (SSIA) to establish and develop trade and technical cooperation between the electronics and semiconductor industries of both the countries.

- Gujarat is expected to have its first semiconductor wafer fabrication manufacturing facility by late 2017 in Prantij of Sabarkantha district. The facility, which will be set up by Hindustan Semiconductor Manufacturing Corporation (HSMC), will employ over 25,000 people including 4,000 direct employees. HSMC along with ST Microelectronics (France/Italy) and Silterra (Malaysia) will set up two manufacturing units each with capacity of producing 20,000 wafers per month.

Government Initiatives

- In the Union Budget 2017-18, the Government of India increased the allocation for incentive schemes like the Modified Special Incentive Package Scheme (M-SIPS) and the Electronic Development Fund (EDF) to Rs 745 crore (US$ 111 million) for providing a boost to the semiconductor as well as the electronics manufacturing industry.

- The Union Cabinet has approved incentives up to Rs 10,000 crore (US$ 1.47 billion) for investors by amending the M-SIPS scheme, in order to further incentivise investments in electronics sector, create employment opportunities and reduce dependence on imports by 2020.

- The Ministry of Electronics and Information Technology plans to revise its policy framework, which would involve the government taking a more active role in developing the sector by providing initial capital, with the aim to attract more private players and make India a global semiconductor hub.

- Mr Ravi Shankar Prasad, Union Minister of Electronics and Information Technology, inaugurated an Electropreneur Park at University of Delhi’s South Campus, which would incubate 50 early stage start-ups and create at least five global companies over a period of five years.

- The ESDM industry will benefit from the government's “Make in India” campaign and is projected to see investment proposals worth Rs 10,000 crore (US$ 1.5 billion) over the next two years, according to

the India Electronics and Semiconductor Association (IESA), an industry body.

- The Government of Telangana plans to launch T-Works in Hyderabad, which will act as a prototyping centre for electronics, semiconductors and hardware start-ups on the lines of California State's Innovation Hub or iHub.

- The Government of India has taken several steps to boost domestic production of electronic items and reduce dependence on imports. Some of these steps include imposition of basic customs duty on certain items falling outside the purview of IT Agreement, exemption from SAD on inputs/components for PC manufacturing, imposition of education cess on imported electronic products for parity, etc.

- Gujarat government is planning to set up an electronics products manufacturing hub in the state, through its newly announced Electronics Policy 2016, which will generate about 500,000 jobs in the electronics sector in the next five years.

- The government also plans to invest US$10 billion in two computer chip manufacturing facilities with a view to create an ecosystem that lays the focus on high-end innovation.

- The Union Cabinet has reconstituted an empowered committee on setting up semiconductor wafer fabrication manufacturing facilities in the country.

Road Ahead

The government, in consultation with semiconductor industry, has increased focus on the ESDM sector in last few years. Some of the initiatives outlined in the National Electronics policy and the National Telecom policy are already in the process of implementation, such as Preferential Market Access (PMS), Electronics Manufacturing Clusters (EMC) and Modified Special Incentive Package Scheme (M-SIPS). With the implementation of fabrication capabilities in India, the country could achieve a degree of self-sufficiency in electronics.

The growing demand for IT hardware, office automation products and consumer electronics products such as mobile phones and automotive products are driving the demand for semiconductors in India.

The major semiconductor end-user segments have been identified as communications, IT and consumer electronics.The categories that are expected to drive the semiconductor market in India are microprocessors, analogue devices, memory chips, discrete circuits and application-specific integrated circuits (ASIC).

Consumption of electronics equipment in India was 1.8 per cent of the global market for electronics consumption in 2005.This is expected to grow to 5.5 per cent in 2010 and 11 per cent in 2015 to reach US$ 363 billion.

Semiconductors are poised to impact modern life.They will open up new possibilities in nano-sciences, biotechnology, medical sciences, electro-mechanical devices, photonics, remote sensing, etc.While still in its nascent stages, the semiconductor sector in India possesses immense potential to emerge as a global hub.

Convergence is the major technological trend in the semiconductor industry, which manifests other trends. Semiconductor technology is consistently scaling down to smaller sizes and geometries, hence a single chip is able to house more and more devices, implying more functionalities per chip.Therefore, a number of previously-used chips are now being merged onto a single chip. Highly-integrated solutions, such as platform solutions, are also Increasingly becoming a trend.

Indian Market Overview of Semiconductor Industries

Introduction

Semiconductor industry, which is now an inseparable part of almost all sectors, has emerged as one of the most important industries. It forms an essential part of all electronic items. It defines how efficiently and smartly we live.

India has become the hub for semiconductor design with nearly 2,000 chips being designed per year and more than 20, 000 engineers are working in various aspects of chip design and verification.

Semiconductor industry is basically divided into fables, which deals with designing and fabrication part, also called the semiconductor foundry, where the final microchip is manufactured. Within semiconductor design, there is very large scale integration (VLSI) design, embedded software and electronic design automation (EDA).

"In India, VLSI holds the biggest chunk in Indian semiconductor design industry," said Mr Kousik Mukherjee, Head-EDA Division, Interra Systems, a US-headquartered company which has its operations in Noida and Bengaluru. While VLSI is big in Bengaluru, Noida holds the biggest chunk of EDA operations happening in India.

Market Size

India has seen growth in consumer electronics as a business and market, especially in the past 10 years. TVs and music systems, and a growing awareness/ need of white-goods seeded the initial growth in the 1970s and phones in the 1980s and 1990s. The past decade has seen a growing demand and market for smart phones, intelligent vehicles, renewable energy (especially solar photo-voltaic), solid state lighting (LEDs), electronics in the healthcare sector, tablets, increasingly sophisticated displays, etc.

Local electronics consumption is expected to touch US$ 400 billion by 2020, which translates into a chip market of between US$ 50 billion and US$ 60 billion. Over the last two years, chip consumption has increased by 61.44 per cent to US$ 8.25 billion.

The electronic system design and manufacturing (ESDM) sector of India is expected to touch US$ 94.2 billion by 2015 from US$ 64.6 billion in 2011, according to a report by the India Semiconductor Association (ISA) and Frost & Sullivan.

Investments

The electronics sector attracted foreign direct investment (FDI) worth Rs 5,986.51 crore (US$ 947.32 million) during April 2000 to June 2013, according to the data released by the Department of Industrial Policy and Promotion (DIPP), Government of India.

Some of the major investments in Indian semiconductor industry include:

- IBM and STMicroelectronics are in advanced stage of talks with the Government of India for an investment worth Rs 50,000 crore (US$ 7.91 billion) to set up India's first chip-making facility

- Cadence Design Systems has announced that it has completed the acquisition of Cosmic Circuits Private Ltd, a Bengaluru-based provider of analog and mixed signal intellectual property (IP) cores. The Cosmic Circuits team will report to Mr Martin Lund, Senior vice president of research and development, SoC Realization Group

- Hitachi High-Technologies Corp has established Hitachi High-Technologies India Pvt Ltd (Hitachi High-Tech India) in Gurgaon, Haryana. The establishment of Hitachi High-Tech India should enable Hitachi High-Tech to demonstrate its global sales and global sourcing capabilities in India, which is a priority region for the Hitachi Group, with the aim of quickly generating annual sales in excess of ¥10 billion in India

- Atrenta Inc has opened a research and development (R&D) facility in Noida, Uttar Pradesh (UP). The new facility houses Atrenta's current staff and meets near-term growth requirements, keeping pace with the company's global expansion plan

- Forte Design Systems has partnered with CircuitSutra to provide VLSI design services throughout India. Forte and CircuitSutra will co-develop ARM AMBA AXI and OCP-IP models compatible with Forte's Cynthesizer SystemC high-level synthesis (HLS)

Government Initiatives

The Government of India has initiated several initiatives for the development of electronics sector in the country. It has recently approved National Policy on Electronics (NPE). The main objective of the policy is to achieve revenues of about US$ 400 billion by 2020 with an investment worth US$ 100 billion and provide employment to around 28 million by 2020. The NPE aims at achieving a turnover of US$ 55 billion of chip design and embedded software industry, US$ 80 billion of exports in the sector. The Government of India also plans to set up over 200 electronic manufacturing clusters.

Some of the initiatives taken by the Government of India for boosting the semiconductor industry of India are:

- The Government of India has approved plans to set up two chip-making facilities that will entail an investment of over Rs 25,000 crore

(US$ 3.95 billion)

- It has approved three projects worth Rs 200 crore (US$ 31.64 million) under the Electronic Manufacturing Clusters (EMC) scheme

- The Indian Government has fast tracked the process of setting up of centres of National Institute of Electronics and Information Technology (NIELIT) in Northeast India

- The Government plans to unveil guidelines to financially support start-ups in the field of electronics. It may invest 15-25 per cent of the total investment for such projects through fund managers including banks or any large IT company

- Under the Union Budget 2013-14, the Government of India has announced that companies investing Rs 100 crore (US$ 15.81 million) or more in plant and machinery during the period April 1, 2013 to March 31, 2015 will be entitled to deduct an investment allowance of 15 per cent of the investment. Most of investment in high tech manufacturing benefit from this due to heavy investment required in fabrication (fab)

- Duty on set top boxes increased from 5 to 10 per cent. It will promote manufacturing of local set top boxes

- Duty on mobile phones priced at more than Rs 2,000 (US$ 31.63) raised to 6 per cent to promote manufacturing of smart phones in India

Road Ahead

The road to emerge as another semiconductor giant has begun for India. Although, India has the requisite expertise in software and design.

India, at present contributes less than five per cent of the total global semiconductor market revenues; however, this share is expected to reach 11 per cent by the end of 2015. Initiatives taken by the Government of India to promote this sector are expected to spur the market in the coming years. The future of the Indian semiconductor design companies will arise with the emergence of fabless design companies from India. These companies would be focusing on creating products for the Indian market. India can take the lead in electronic systems design and electronic product manufacturing. The absence of systems or a legacy creates for India, the unique opportunity to leapfrog technology.

To speed up the foundation of India’s semiconductor & electronics industry, the Union Government has proposed to provide a sum of Rs 10,000 crore (US$ 1.58 billion) as an ‘Electronics Development Fund (EDF)’ to promote electronics hardware manufacturing in the country.

Exchange rate used: INR 1 = US$ 0.0158 as on September 17, 2013

Indian Semiconductor Market is expected to reach US$ XX Bn by 2026 at a CAGR of XX% over the period 2019-2026.

The report includes the analysis of impact of COVID-19 lock-down on the revenue of market leaders, followers, and disrupters. Since lock down was implemented differently in different regions and countries, impact of same is also different by regions and segments. The report has covered the current short term and long term impact on the market, same will help decision makers to prepare the outline for short term and long term strategies for companies by region.

Indian Semiconductor Market Dynamics:

The key drivers for the semiconductor market in India include rising demand for consumer electronics, growing automotive semiconductor market, telecom infrastructure equipment, wireless handsets, notebooks and IT automation products, set-top boxes and smart cards. Booming the Indian Semiconductor Market. Internet of things (IoT) market, Heavy investments in New Product Development and R&D also driving the market in positive direction.

Growth sectors, including health care equipment, automotive, consumer goods and industrial goods, all of which progressively use electronics are

expected to encourage the semiconductor consumption in India by maintaining the anticipated CAGR of XX.XX% and reach to US$ XX.XX Mn by forecast period.

With the location of a wafer fab in India, the country could achieve a level of independence in electronics, and partly cut back the very high supply chain risks that the country is exposed to, without an alternative source for procurement. India is heavily dependent for semiconductor chip imports on Asian countries such as China, Taiwan, South Korea and Japan, although electronic manufacturing service companies in India have reached considerable maturity for final assembly, testing, packaging and distribution services. Chinese and Taiwanese companies compared to western players, are making the major contribution in Indian domestic semiconductor market.

The Indian Semiconductor Market dynamics are thoroughly studied and explained in the report, which helps reader to understand emerging market trends, drivers, restraints, opportunities, and challenges at regional & state level for the Indian Semiconductor Market.

Indian Semiconductor Market is studied by Various Segments:

The report from Maximize market research provides the detail study of the market by various segments. Report segments Indian Semiconductor market by Material Type, Component, Fabrication Technologies, Organization Type and End-User Industries. As per government of India Task Force report (DeitY) gross size of the electronics industry is evaluated at about US$ 1.9 trillion and is anticipated to reach US$ XX.XX trillion by 2027 with the anticipated CAGR of XX.XX%.

Key Developments in the Indian Semiconductor Market:

The ministry of electronics and information technology (MeitY) is revising its policy framework towards making India a global semiconductor hub, which will see the government taking a more active role, including initial investment, in a bid to attract private sector players. The existing policy has not worked as it offered little commercial viability for the private sector. Earlier, a Jaypee-led consortium pulled out midway from a project for setting up of a semiconductor wafer fabrication manufacturing facility. Recently, another consortium, led by Hindustan Semiconductor Manufacturing Corporation (HSMC) including ST Microelectronics and Silterra Malaysia, which had also received approval to set up a fab unit, has been facing challenges in tying up the funding.

The two projects were worth US$ XX.XX Mn. Still, India has a competitive advantage over other countries because of its large engineering skill pool. It offers a large pool of a technically and scientifically-skilled workforce. At the same time, the country has ample semiconductor design talent at competitive costs.

Indian Semiconductor Market: Competition Landscape

The Indian Semiconductor Market has the presence of a large number of players. Major players in the Indian Semiconductor Market are concentrating on developing new technologies to facilitate the industry with lowest time and low expenditure consuming technologies. In the recent years there are many discoveries in the field of technologies with regards to Indian Semiconductor Market, which in turn will help the industry to grow resulting in boost to the competition too. Detailed analysis of competition, new entrants, strategic alliances, mergers and acquisition in the Indian Semiconductor Market is covered in the report.

The report covers the market leaders and followers in the industry with the market dynamics by region. It will also help to understand the position of each player in the market by region, by segment with their expansion plans, R&D expenditure and organic & in-organic growth strategies. Long term association, strategic alliances, supply chain agreement and mergers & acquisition activities are covered in the report in detail from 2014 to 2019. Expected alliances and agreement in forecast period will give future course of action in the market to the readers. All major & important players are profiled, benchmarked in the report on different parameters that will help reader to gain insight about the market in minimum time.

Indian Semiconductor Market, Objective of the Report:

The objective of the report is to present a comprehensive analysis of Indian Semiconductor Market including all the stakeholders of the industry. The past and current status of the industry with forecasted market size and trends are presented in the report with the analysis of complicated data in simple language. The report covers all aspects of the industry with a dedicated study of key players that includes market leaders, followers and new entrants by region. PORTER, SVOR, PESTEL analysis with the potential impact of micro-economic factors by region on the market are presented in the report.

External as well as internal factors that are supposed to affect the business positively or negatively have been analyzed, which will give a clear futuristic view of the industry to the decision-makers. The report also helps in understanding Indian Semiconductor Market dynamics, structure by

analyzing the market segments and project the Indian Semiconductor Market size. Clear representation of competitive analysis of key players by type, price, financial position, product portfolio, growth strategies, and regional presence in the Indian Semiconductor Market make the report investor's guide.

Indian Semiconductor Market, by Material

- Silicon
- Germenuim
- Carbon
- Tin
- Others

Indian Semiconductor Market, by Fabrication Technologies

- Metalorganic vapour phase epitaxy (MOVPE)
- Molecular beam epitaxy (MBE)
- Hydride vapour phase epitaxy (HVPE)
- Liquid phase epitaxy (LPE)
- Metal-organic molecular beam epitaxy (MOMBE)
- Atomic layer deposition (ALD)

Indian Semiconductor Market, by Component

- IC
  - IC Design
  - IC Manufacturing
  - IC Packaging and Testing
- O-S-D

Indian Semiconductor Market, by Organisation Type

• Large Enterprises

• SMEs

Indian Semiconductor Market, by End User Industry

• Electronics

• Telecommunication

• Information & Technology

• Data Processing

• Automotive

• Industrial Machinary

• Consumer

• Others

Key Players in Indian Semiconductor Market

NXP Semiconductors

Cisco Systems (India) Pvt. Ltd.

Adroit IC Design

Ineda Systems

Semiconductors India Pvt. Ltd.

Cadence Design Systems (India) Pvt. Ltd.

D’GIPRO Systems Pvt. Ltd.

DCM Data Systems Ltd.

Digital-X (India) Pvt Ltd.

HCL Technologies India Pvt. Ltd.

HiQ Networks (India) Pvt. Ltd.

IBM Global Services India Pvt. Ltd.

IKOS India Pvt. Ltd.

Silicon Automation Systems (India) Pvt. Ltd. (SASI)

Sand Microelctronics (I) Pvt Ltd

Silicon Interfaces

Smart Modular Tech.

Spike Technologies (India) Pvt.Ltd.

Shonk Technologies ltd

Semiconductor Complex Ltd.

Tata Elxsi Ltd.

Tata Infotech Ltd.

Texas Instruments (India) Ltd.

Section: 3

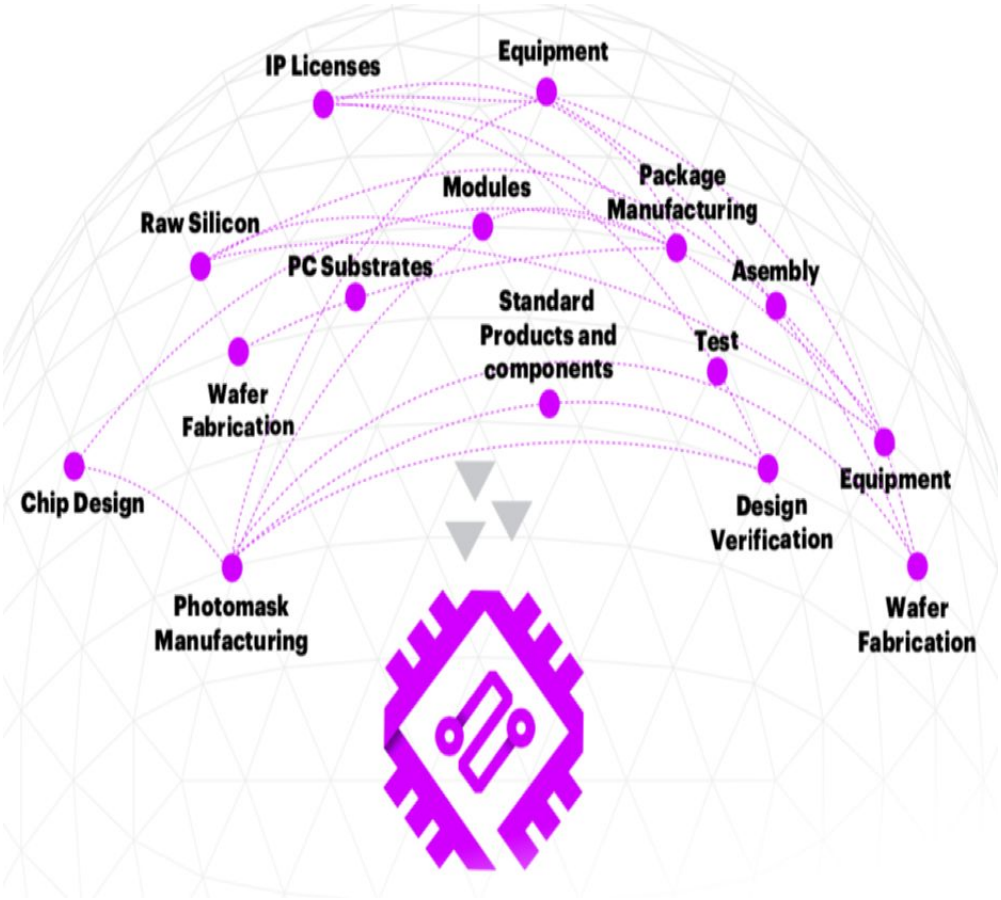
Ecosystem of Semiconductor industry

Ecosystem of Semiconductor industry

The semiconductor industry is a truly global affair. Around the world, semiconductor chip designers use intellectual property (IP) licenses and design verification to provide designs to wafer fabricators, which use raw silicon, photomasks, and equipment to create chips for package manufacturing to assemble with printed circuit board (PCB) substrates for delivery to end customers. In fact, components for a chip could travel more

than 25,000 miles by the time it finds its way into a television set, mobile phone, automobile, computer, or any of the millions of products that now rely on chips to operate.

Components for a chip could travel more than 25,000 miles before completion



The Global Semiconductor Alliance (GSA) and Accenture have teamed up to conduct a joint study on the globality and complexity of the semiconductor ecosystem to explore the interdependencies and benefits of the cross-border partnerships required to produce semiconductors, as well as to illustrate what's needed to keep this global ecosystem operating efficiently and profitably.

Industry executives can use this study to inform their company strategies, as well as to educate non-semiconductor partners, including policy makers, on the nature of their business to promote a better understanding of the important role semiconductors play in everyday life and on the globe-spanning ecosystem that's needed to produce them.

Semiconductors have become an essential part of everyday life around the world

“The value of the industry is driven by a diverse worldwide base—electronics demand is so broad-based,” said Rick Clemmer, chief executive officer of Netherlands-based NXP Semiconductors. “Technology is critically important to continue improving GDP.”

A wide range of emerging technologies (including Artificial Intelligence, Automotive Electronics, Industrial Internet of Things, and Augmented / Virtual Reality) are gaining prominence across industries as more and more companies find new ways to use them to create compelling new products and to transform their businesses. And at the heart of all of these technologies are the chips that make them work. In fact, more than ever, the entire tech world depends on the semiconductor industry to provide the computing power necessary for all these technologies to fulfill their potential. That includes millions of individuals around the world.

As technology becomes more connected, autonomous, virtual, and intelligent, semiconductors play an increasingly significant role in individuals’ lives—whether they know it or not. At their essence, semiconductors serve as a translator from the physical world to the digital world, and many products and applications we now take for granted simply wouldn’t be possible without them.

Take, for example, something millions of people carry with them every day and rely on
to capture and share their memories: their smart phone’s digital camera. Semiconductor sensors inside the camera turn the physical-world image of what the lens sees into digital data. Additional software then converts the digital data into an image file that people can post on social media, text or email to friends and loved ones, and store for posterity.

What about smart speakers powered by voice assistants? Or the connected thermostats and lights in the home? Or intelligent systems in cars that continually monitor operations to ensure the vehicle is running correctly? These and many others are also examples of technologies people rely on daily that owe their existence and utility to semiconductors.

Global collaboration is vital for success in semiconductors

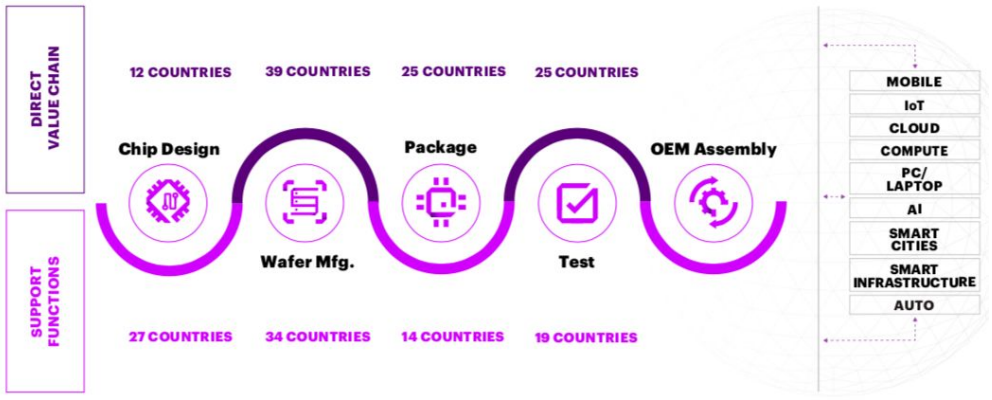
Many materials are required to make a semiconductor chip—among them, silicon, photoresist, and rare metals—and numerous sub-segment technologies are required to turn these materials into finished chips. When everything is said and done, the making of one semiconductor chip requires

thousands and thousands of people, most of whom have specialized knowledge and specialized jobs, spanning myriad industries, countries, and regions.

Indeed, the semiconductor industry is a global ecosystem in every sense of the word. According to our research, each segment of the semiconductor value chain has, on average, 25 countries involved in the direct supply chain and 23 countries involved in supporting market functions (Figure 2). In fact, a semiconductor product could cross international borders approximately 70 or more times before finally making it to the end customer.

Wafer fabrication is the most globally dispersed, with 39 countries directly involved in the supply chain and 34 involved in market support (including photolithography equipment, etching and cleaning tools, deposition equipment, and fabrication facility support equipment). Direct involvement in wafer design spans 12 countries, while direct product testing and package manufacturing each are done across 25 countries.

Figure 2: The total number of countries participating in semiconductor manufacturing is significant



Global scale has many benefits

The global expansion of the semiconductor industry over the past two decades is not the result of chance. Rather, the executives we interviewed indicated the semiconductor industry has actively pursued global scale because it benefits not only individual companies, but the industry as a whole—in several important ways.

IT RESULTS IN BETTER PRODUCTS

In an industry that's the primary driver of technology innovation, sourcing that innovation globally is critical. The ability to take advantage of the best talent, experience, and perspectives—regardless of where they are in the world—enables semiconductor companies to continue generating the

advancements that fuel this industry and are increasingly important to the lives of people everywhere.

As Clemmer noted, “Diversity – whether related to country, gender, or thought – is important for any company to ultimately be successful."

IT FILLS CRITICAL BUSINESS NEEDS THAT CAN’T BE MET LOCALLY

Because the semiconductor industry’s requirements are highly technical and specific, the industry’s players can’t succeed without deep specialization and expertise. In much the same way global trade fuels specialization and increased efficiency at the macroeconomic level, so too does globality fuel the semiconductor industry’s ability to achieve its business priorities.

This very survival, however, will be challenged as the underlying technology becomes a larger part of geopolitical conversation. Tariffs are one of the biggest threats to the effective functioning of the semiconductor industry, and any tariffs enacted for the industry will have an impact not only on ecosystem participants, but also on companies and consumers downstream.

Lack of global collaboration will also boost prices, according to Simon Segars, chief executive officer of ARM in the United Kingdom. “If the only thing you can use is what’s supplied locally, that will increase prices and reduce a country’s competitiveness.”

IT HELPS MITIGATE RISK

Having access to a global supplier network decreases the risk to a company’s supply chain, which is important due to the amount of money and business at stake.

One example of how global collaboration mitigates risk is seen in the way it has helped the semiconductor ecosystem minimize the impact of natural disasters. The industry’s players have been able to shift around the affected areas as necessary to keep the ecosystem up and running and minimize the disaster’s impact.

“The semiconductor industry has demonstrated the value of globality after natural disasters,” noted Steve Kelley, president and chief executive officer of United States- based Amkor Technology. “Time and time again, flexible supply chains have allowed us to adapt quickly, maintaining continuity of supply after earthquakes, tsunamis, and floods.“

Andy Micallef, chief operations officer at Marvell Semiconductor in the United States, agrees. “Look at incidents over the past 10 years,” he said.

“Supply interruptions typically rely on global relationships to help each other out."

A highly visible example is the March 2011 9.0 earthquake and tsunami in Japan. Most of the manufacturing plants in the disaster area were severely affected, and buildings and roads suffered significant damage. The impact on the semiconductor industry was significant, as Japan represented about 20 percent of the worldwide semiconductor market revenue at the time. The response was profound: Semiconductor companies, employees, and equipment suppliers worked together with government agencies to bring production back to pre-earthquake levels in three months. Additionally, the industry’s globality afforded companies the chance to evaluate their sourcing options and create a more diverse set of qualified suppliers with backup suppliers to mitigate such risks.

IT ENABLES COMPANIES TO MORE EFFECTIVELY DEAL WITH COMPLEXITY

Micallef noted that when dealing with complexity, money isn’t enough to overcome individual companies’ resource constraints. “This industry has a small number of people and a large amount of capital,” he noted. “Relationships across the globe are critical.”

It’s time for a global standard that sets the ground rules for how the industry works together

While globality is critical to the semiconductor industry, it’s not without its challenges. One of the most obvious is politics. Ongoing concerns around international policy have a clear impact on strategic decisions, potentially causing businesses to rethink their strategy or limit their business dealings to partners from a specific region Companies need to ensure they can operate in an environment that enables them to take full advantage of their partner relationships. This includes an implicit understanding of the industry’s challenges and how companies can advance their capabilities while respecting implied boundaries that come with participation in a global industry, as well as sufficient safety mechanisms to de-risk exposure to globality.

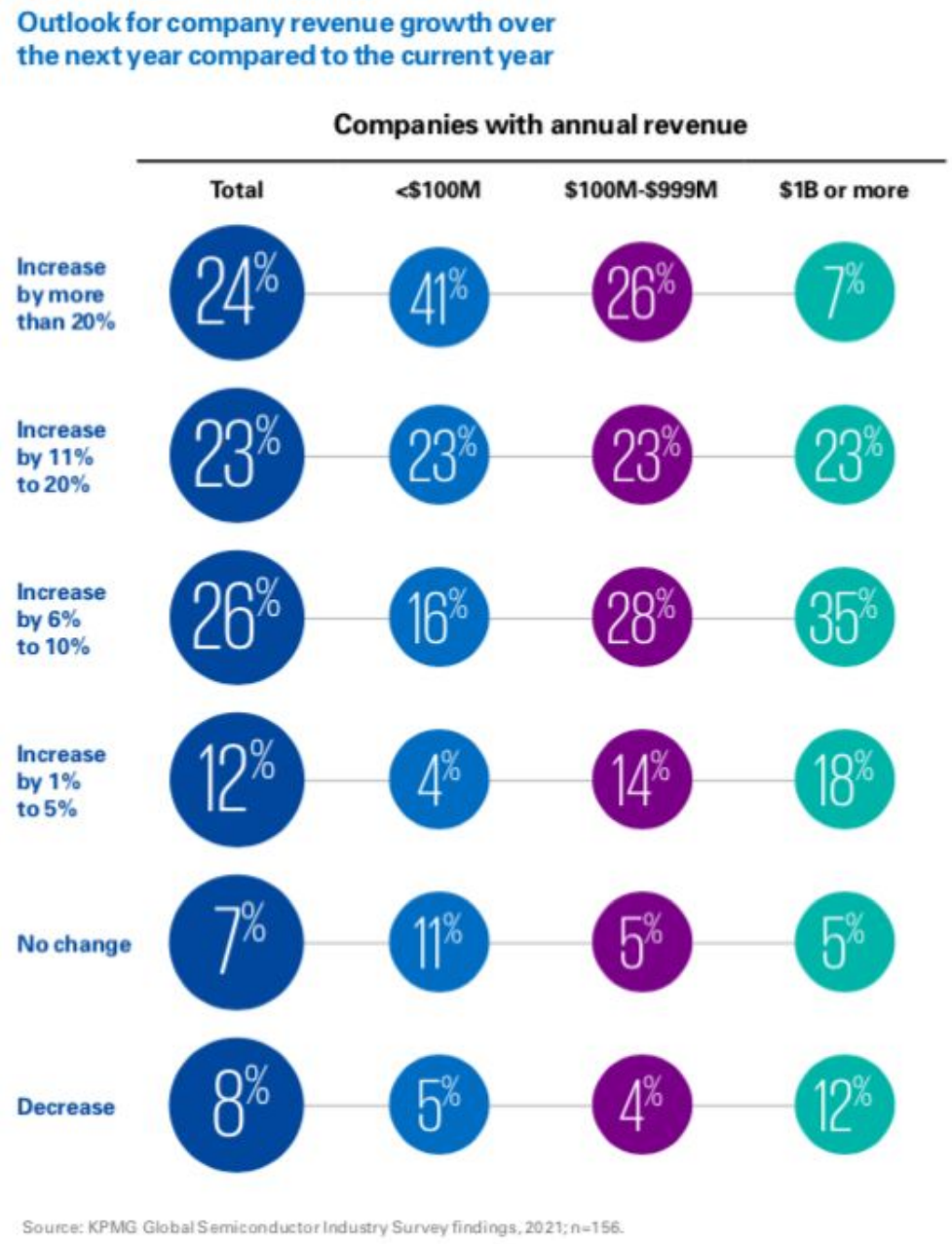
In this regard, a global standard for collaboration and IP protection could go a long way toward addressing the potential complications inherent in an industry where hundreds of companies spanning dozens of countries—each of which has its own rules, goals, and culture—must work together.

According to executives participating in our research, a global standard for how semiconductor companies work together and maintain vital IP protection would continue to foster the widespread and effective collaboration critical to success. They agreed that a global standard would help minimize threats, such as IP theft, that could lead to a scaling back of global collaboration in favor of relationships closer to home that could be more easily controlled.

“But I’d like to think we don’t end up in a Balkanized world where companies are building regional solutions. This is an area that is ripe for innovation. We as leaders of the semiconductor industry must be able to debate and discuss the need for legal and ethical standards for how we treat each other. We must lobby for recognition of a global standard.”

This initiative was front and center at the World Semiconductor Council (WSC), a global council of semiconductor industry executives from Asia-Pacific, Europe, and North America. On May 23, 2019, the WSC held its 23rd annual meeting of the WSC in Xiamen, China, where the organization issued the following statement:

Intellectual property (IP) is the lifeblood of the global semiconductor industry, and respecting and enforcing intellectual property rights is essential to the industry’s global competitiveness. The global semiconductor industry invests over 10% of revenue into R&D, one of the highest proportions of any industry. The trend worldwide in the last decade, and in most WSC member countries, is for significant growth in patent applications and patent grants. Therefore, protection of the IP that results from this R&D (i.e., patents, trade secrets, source code, etc.) is essential to the industry’s competitive position, and to preserving incentives for innovation. The WSC encourages the Governments/Authorities Meeting on Semiconductors (GAMS) to ensure that intellectual property is strongly protected and enforced in their domestic laws and regulations.”



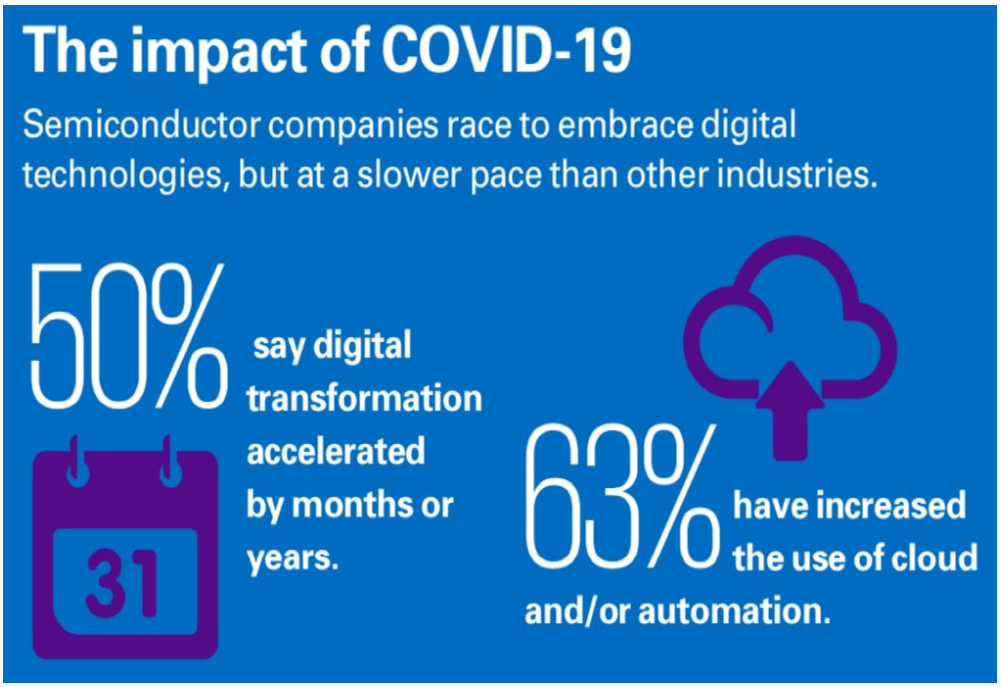
The Impact of Covid-19 on Semiconductor Industry

2020 brought many unforeseen challenges to the global semiconductor industry. The COVID-19 pandemic and ensuing global economic downturn put pressure on industry fundamentals, temporarily closing manufacturing plants, disrupting day-to-day business, compromising supply chains, and reducing chip order expectations in the short- term. Meanwhile, election year uncertainty in the United States made it difficult for semiconductor leaders to anticipate regulatory and policy changes related to global trade and tariffs. Some long-term uncertainty remains,but the impacts of COVID-19 on the

semiconductor industry appear more favorable than those seen in other sectors.

For the most part, semiconductor companies mobilized quickly to understand and respond to the near-term effects of these disruptions. Massive digital acceleration is underway by consumers and enterprises as more people stay home for both work and play and increase their reliance on technology. This is driving a surge in demand for chip based products and solutions that power our hyper-connected society. Semiconductor companies and their customers are building up inventory as buyers place big bets on products they will need to serve their own growing markets. Whereas COVID-19 devastated a number of other industries, it became a net catalyst for growth for semiconductor companies.

Industry experiences a roller coaster year


The impact of COVID-19
Semiconductor companies race to embrace digital technologies, but at a slower pace than other industries.
50%
say digital transformation accelerated by months or years.
31
63%
have increased the use of cloud and/or automation.

The semiconductor industry has proven resilient throughout the COVID-19 pandemic, surprising many industry watchers and again illustrating the world's increasing reliance on advanced technologies.

Most leading research firms predicted single digit growth for the industry prior to 2020 and even into the first few months of the year. Further opinions collected in the spring, when the pandemic had forced global businesses and societies to lockdown in large numbers, estimated industry-wide revenue to drop 5 to 10 percent year over year. After demonstrating strong resilience through the crisis, the industry finished 2020 with revenue growth of 6.5 percent. As it turned out, the impacts of COVID-19 depended greatly on individual circumstances. The sector saw wild swings in

performance on a company- by-company basis. Some smaller companies that were exposed to a hard hit customer or end market saw their sales drop significantly, while more diversified semiconductor companies saw their revenue soar.

Looking broadly across the ecosystem and towards the future, however, the picture is optimistic. Semiconductor companies' strong focus on business continuity and resiliency, due to traditionally long lead times for R&D and product development, appears to have put the sector in a strong position to respond to COVID-19 disruption. And future growth opportunities abound as all aspects of life—from work to education to healthcare to entertainment—will increasingly need the technologies and related cloud infrastructure that semiconductors enable.

Digital transformation is accelerating, but pace lags other industries

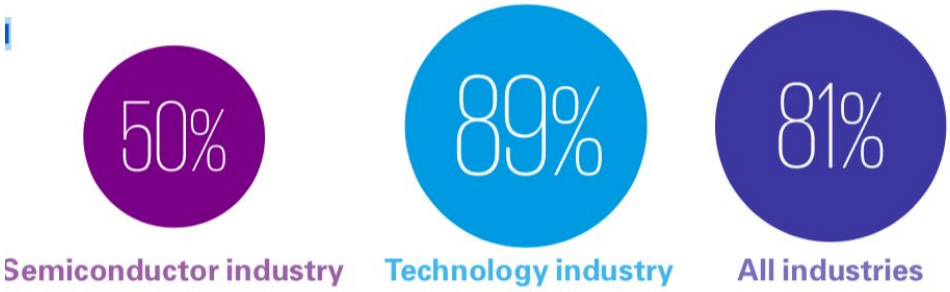
COVID-19 forced many manufacturers and suppliers to update their systems and operating models due to remote workforces and the need to become more efficient and cost effective. Digital transformation encompasses coupling powerful new technologies such as AI, blockchain, IoT, automation and 5G with business model and organizational changes to help drive value and enable growth.

Fifty percent of respondents say COVID-19 has accelerated their companies' digital transformation progress by months or years. This may seem like an impressive number but across the global technology sector 89 percent of company leaders reported similar progress in digitizing their operations, as revealed in the KPMG Technology Industry CEO Outlook report. And across all industries, 81 percent of CEOs state their operational digital transformation efforts have accelerated by months or years per the KPMG 2020 CEO Outlook report. Further, as discussed in the strategic priorities section, only 33 percent of semiconductor leaders say digital transformation is a top three strategic priority.

Why would one of the most innovative sectors apparently lag behind others in digital transformation? One argument is that the industry is already ahead of the broader market, with more advanced digital capabilities embedded into enterprises, so not every industry started from the same point. Or perhaps the great demand for semiconductor products due to COVID-19 offers an explanation. As producers of the critical components of in demand technology products, semiconductor companies had to retrench during the early days of the pandemic and focus on immediate supply chain and other business continuity issues. This may have been done at the

expense of longer-term digital optimization investments that have a longer payoff period.

Industry leaders reporting their digital transformation has accelerated by months or years due to COVID-19



In addition to enterprise-wide digital transformation, the organizational and operational changes required to compete in the new reality are significant. Traditional industry structures are too linear and inflexible to serve today's interconnected and customer-centric world.

As a result of the ongoing pandemic, semiconductor companies plan to implement a variety of other organizational and operational changes in an effort to ready their businesses for the future:

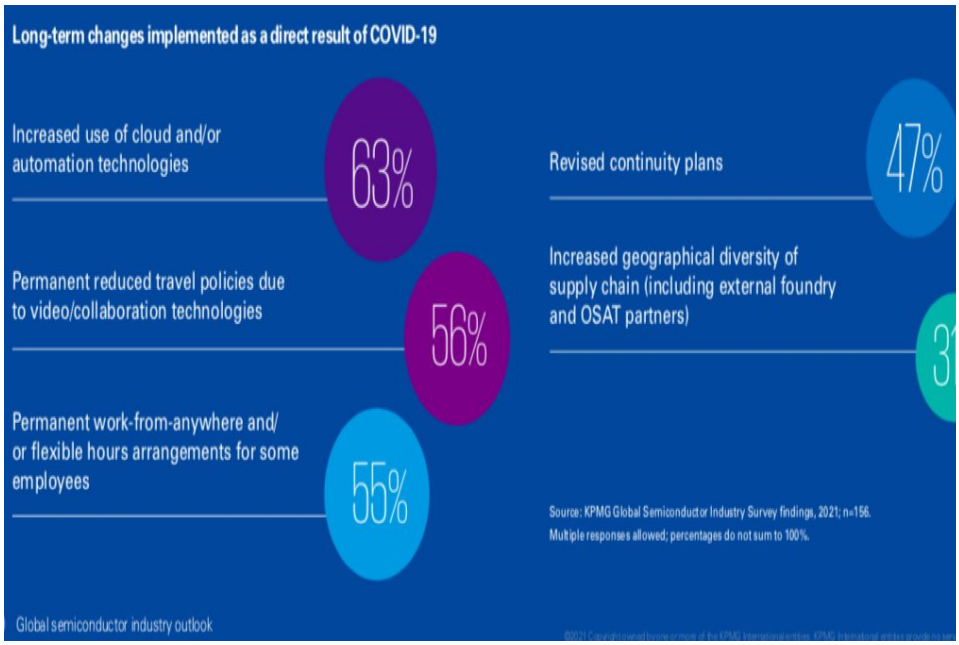
—Increasing the use of cloud and automation technologies

—Implementing permanent work-from-anywhere policies enabled by digital collaboration tools and video conferencing.

Enhancing how employees work across business functions is a key focus of operational investments. Semiconductor companies see an opportunity to leverage remote work models to drive greater productivity, particularly from in-demand talent like engineers and data scientists that perhaps had less experience collaborating remotely in the old, geography-bound model. The survey findings show that the industry's back-office workers are most likely to work
from home in the future, but even some R&D professionals will be afforded this opportunity.

Financial Expectations

Revenue and profitability outlook positive


Long-term changes implemented as a direct result of COVID-19
Increased use of cloud and/or automation technologies
63%
Permanent reduced travel policies due to video/collaboration technologies
56%
Permanent work-from-anywhere and/ or flexible hours arrangements for some employees
55%
Revised continuity plans
47%
Increased geographical diversity of supply chain (including external foundry and OSAT partners)
Source: KPMG Global Semiconductor Industry Survey findings, 2021; n=156.
Multiple responses allowed; percentages do not sum to 100%.
Global semiconductor industry outlook

Despite enduring the impacts of COVID-19 in 2020, most semiconductor companies maintain a positive growth outlook for the year to come.

Across all company sizes, 85 percent of survey respondents predict their companies' revenue will increase next year compared to the current year. These expectations are prevalent across all company sizes, indicating a healthy level
of optimism about the industry's future. Smaller companies are particularly confident.

Seventy-nine percent of semiconductor leaders also predict industry-wide profitability to increase compared to last year. KPMG believes this is due to two primary factors:

1) More strategic spending
2) Increased demand driven by today's rapid technological innovation

COVID-driven digital acceleration across both business and consumer markets
is prompting customers to order certain semiconductor components ahead of time, as opposed to real-time inventory purchasing. Although an inventory correction may be coming down the road even if chip companies make no further cost reductions this year, they seem confident they will be able to generate increased profits based on pricing advantage alone.

Respondents are so bullish on growth and profitability that nearly three quarters (73 percent) plan to increase capital spending in 2021, compared to only 59 percent the year prior.

Companies seek efficiencies

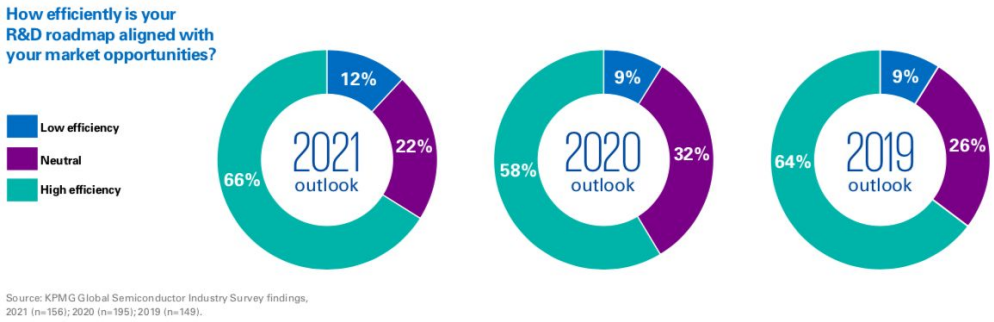
Semiconductor companies have experienced some COVID-driven cost-cutting this year, including headcount trimming and business travel reduction. Virtual work environments have forced semiconductor companies to become more creative and agile in how they get work done and now appear ready to make some of those changes permanent. Fewer respondents than last year plan to expand their workforces (63 percent compared to 74 percent). Physical location is no longer a limiting factor in new work models, allowing companies to derive greater productivity from existing workforces unconstrained by geography.

The industry also reports significant efficiency in R&D, a key driver of profitability growth. Two-thirds of respondents (66 percent) say their companies' R&D roadmap is well aligned with market opportunities. While this represents an encouraging figure, a significant opportunity remains for one third of industry players.

New work models and other adjustments to organizational structures may be the ticket to seizing these new opportunities. As the semiconductor industry moves towards providing services and solutions versus stand-alone chips, organizations that operate in a modular, integrated, and customer-centric way will be better able to generate relevant, profitable innovations. Specialized sales and support models, supported by new people, process and technology capabilities, will enable companies to understand customer needs at a deeper level and customize content and solutions accordingly.

Innovation investment is consistently a top line item on semiconductor budgets and it will remain so in 2021: 71 percent of companies will spend more on R&D next year in order to create strategic design wins and develop new products necessary to drive competitive advantages in diverse applications and end markets. Thirty-four percent of respondents from smaller companies expect to increase R&D spending 20 percent or more, compared to just 12 percent of mid-size companies and two percent of large enterprises.

Building out a diversified portfolio is difficult in any industry, and especially in an innovation-centric one like semiconductors. Once semiconductor companies achieve a certain size threshold they typically expand into multiple products, challenging their R&D focus and execution.



Source: KPMG Global Semiconductor Industry Survey findings, 2021 (n=156); 2020 (n=195); 2019 (n=149).

Growth products & applications

Sensors/MEMS are the leading product category

Despite unprecedented social and economic disruption brought on by an unexpected global pandemic, the prime semiconductor opportunity areas (products and applications) are largely unchanged from last year's survey.

From a product perspective, survey respondents view most categories with increased growth potential. Sensors/MEMS were selected as the number one growth product, retaining the top spot this year. Analog/RF/Mixed signal was ranked second, followed by the GPU/MCU/MPU category.

Technology penetration in consumer, enterprise, and industrial devices, together with mainstream adoption of IoT and 5G technology, continue to drive significant growth in revenue and investments. Automotive is another category that is driving the growth of these products as all levels of assisted-driving and autonomous vehicles are increasing the use of these components.

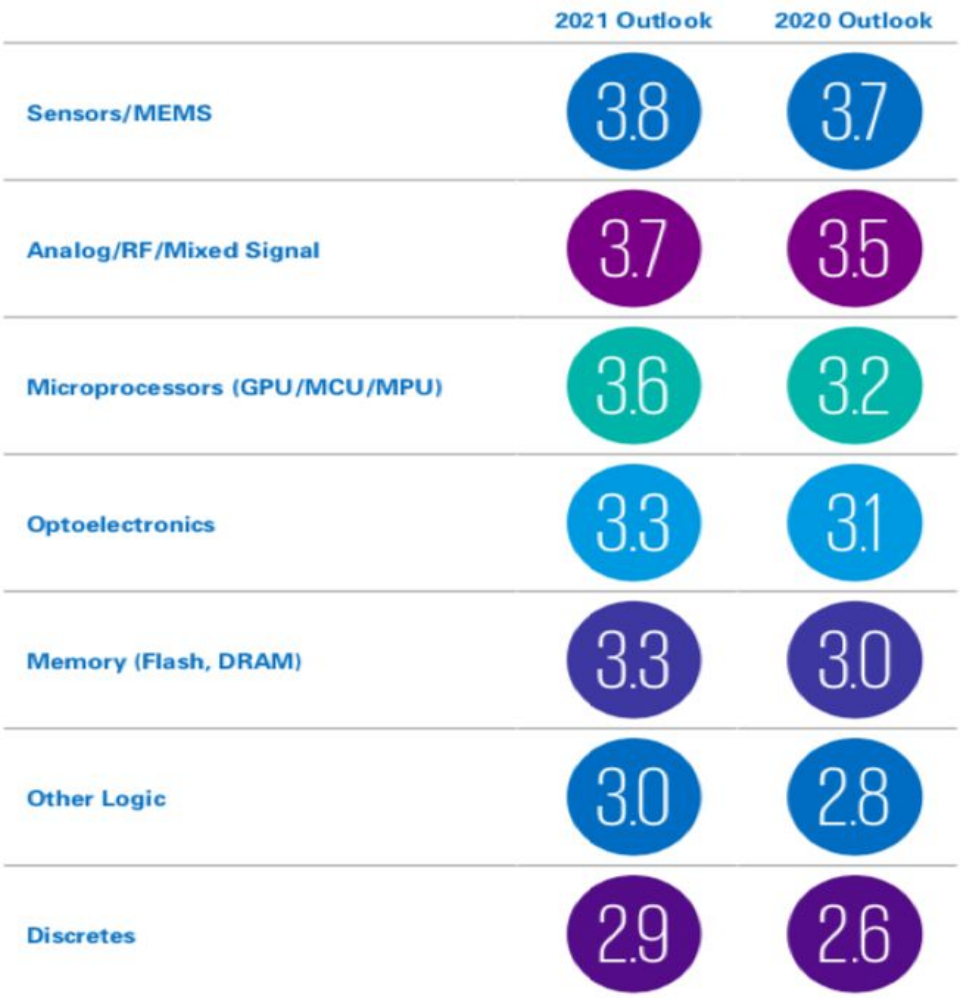
Analog/RF/Mixed signal, a critical component for power management, will also continue to be a key revenue producer. With many employees and students working virtually, it's no wonder that among revenue-driving applications, wireless devices and personal computers saw an uptick in importance year-over- year. As technology becomes an increasingly integral part of our daily lives, each additional laptop, tablet, cellphone, and personal computer sold needs strong battery life. Analog is the product required to manage it.

Microprocessors (including GPU/MCU/MPU) repeats as the third-ranked growth product, and its importance jumped the highest year-over-year relative to other products. Corporations are rearchitecting technology

infrastructure to support compute-intensive use cases and workforce virtualization by investing in GPU purchases to power cloud, server, and data center technologies.

Products representing growth opportunity for the semiconductor industry over the next year

(Averages on a 1 to 5 scale with 1=Low growth opportunity and 5=High growth opportunity.)



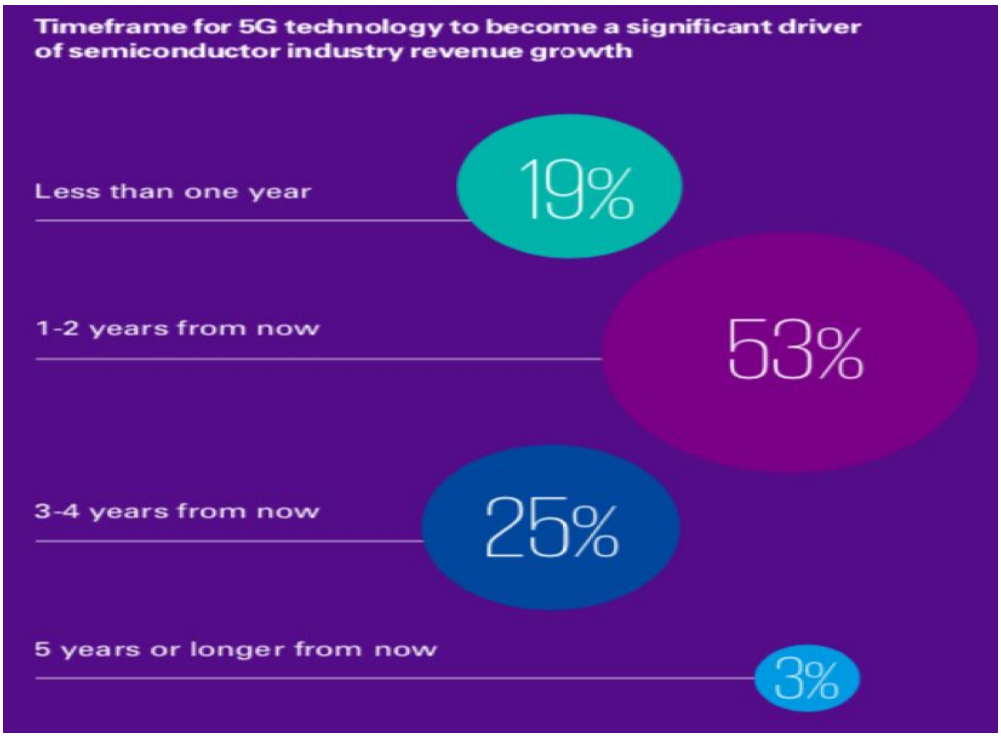
Source: KPMG Global Semiconductor Industry Survey findings, 2021 (n=156); 2020 (n=195).

Wireless, IoT, and automotive applications driving growth

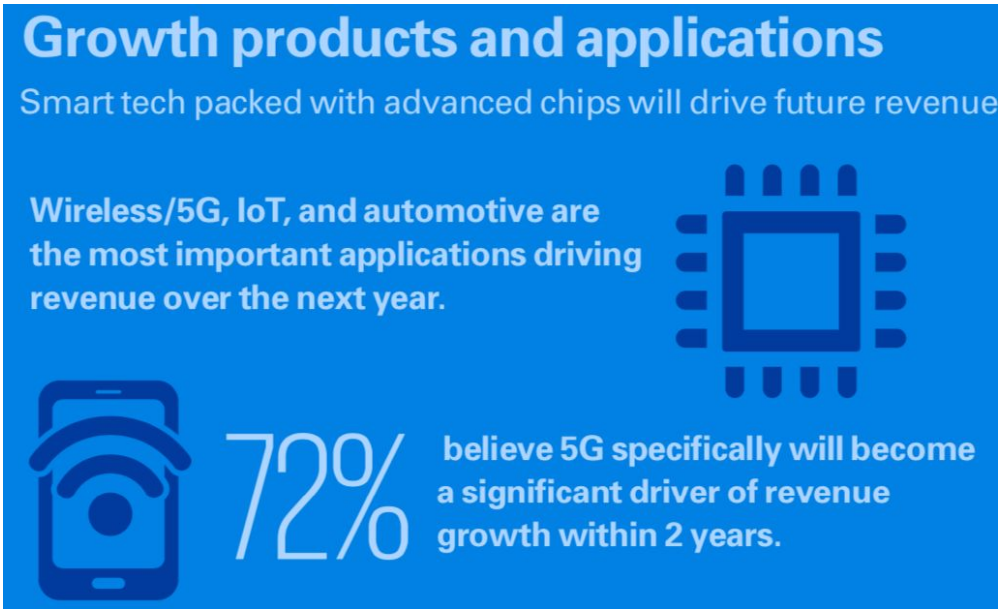
Wireless communications and IoT, the two leading applications in the prior year survey, are tied as the most important applications driving semiconductor revenue over the next year. COVID-19 is spurring even greater interest and uptake of 5G communications by consumers and businesses, which now have greater need for high speed wireless bandwidth.

Survey respondents say COVID-19 has increased customer integration of key technologies into their products, such as IoT and 5G. The buildout of 5G networks and infrastructure, which started well before COVID-19, is now driving new IoT use cases and creating the need for more powerful sensors and software to sync them up.

Seventy-two percent of industry leaders believe 5G will become a significant driver of industry revenue within the next two years. In last year's survey, only 50 percent felt this way.


Timeframe for 5G technology to become a significant driver of semiconductor industry revenue growth
Less than one year
19%
1-2 years from now
53%
3-4 years from now
25%
5 years or longer from now
3%

Despite the economic downturn and work-from-home mandates caused by COVID-19, the automotive sector retained its importance for the upcoming year, remaining the third-leading application expected to drive semiconductor revenue.


Growth products and applications
Smart tech packed with advanced chips will drive future revenue
Wireless/5G, IoT, and automotive are the most important applications driving revenue over the next year.
72%
believe 5G specifically will become a significant driver of revenue growth within 2 years.

Industry issues & strategic priorities

Territorialism dominates industry issues

Over the next three years, industry leaders believe that territorialism—including cross-border regulation, tariffs, new trade agreements, and national security policies—will be the biggest issue facing semiconductor companies by a large margin. More than half (53 percent) of respondents rank it as a top three concern, up 16 points from the prior year survey. Respondents are more anxious about trade deal renegotiations, tariffs, and the nationalization of semiconductor technologies than other issues.

Nationalistic technology and trade policies—particularly by the world's two biggest economies, the U.S. and China—add cost pressure and supply chain complexity throughout the semiconductor ecosystem. Tariffs on imported or exported components increase manufacturing costs, spurring companies to explore various tariff mitigation strategies. They similarly create logistical and compliance challenges.

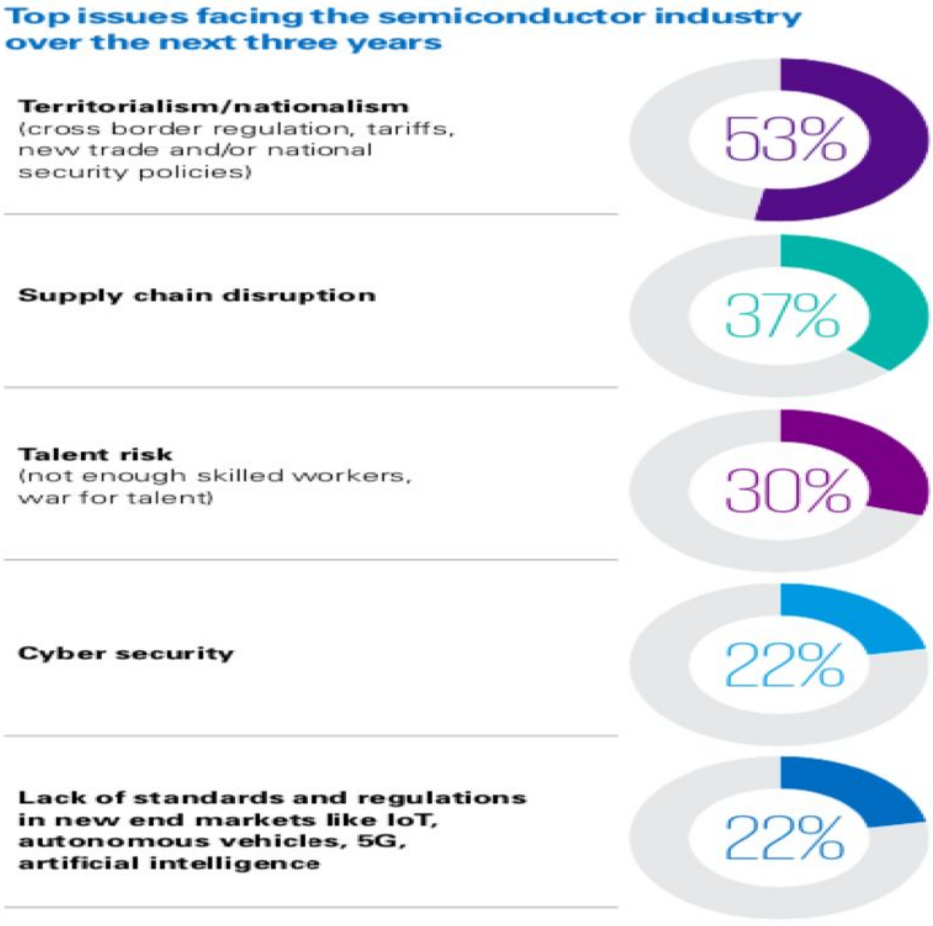
Supply chain disruption also saw a jump in the rankings. Managing rising trade and tariff costs continues to occupy the semiconductor agenda, with some manufacturers making significant changes to re- optimize the supply chain, such as sourcing chip content from different geographies.

Industry issues and strategic priorities
Nationalist trade environment challenges semiconductor companies.
53%
name territorialism the biggest industry issue.
<5%
rank inclusion and diversity, reducing carbon footprints, and formalizing ESG reporting as one of their top three strategic priorities.

COVID-19 is a key contributing factor, although less damaging to the industry supply chain than many anticipated. During the initial lockdown period, global manufacturers experienced some temporary problems; however, there were few lasting supply bottlenecks and component availability did not suffer drastically. With mature, established,

global supply chains, semiconductor companies typically have better resiliency to disruption than other industries, and that largely proved out during COVID-19.

Talent risk, virtually tied for the top industry issue last year, fell to third place. While still an important concern, perhaps the new work-from-anywhere paradigm helps provide an explanation. Sixty-four percent of tech company CEOs in the KPMG Technology Industry CEO Outlook report stated that remote working has widened their potential talent pool, making it easier to source required talent.


Top issues facing the semiconductor industry over the next three years
Territorialism/nationalism (cross border regulation, tariffs, new trade and/or national security policies)
53%
Supply chain disruption
37%
Talent risk (not enough skilled workers, war for talent)
30%
Cyber security
22%
Lack of standards and regulations in new end markets like IoT, autonomous vehicles, 5G, artificial intelligence
22%
Source: KPMG Global Semiconductor Industry Survey findings, 2021; n=156.
Multiple responses allowed; percentages do not sum to 100%.
Partial list of responses shown.

Section: 4

Understanding Semiconductor Business

Different Types of Semiconductor Industries

There are different types of semiconductor companies:

1. Design companies.

1. Manufacturers.

1. Vertically integrated design and manufacturing companies. e.g. Intel, IBM, Samsung

1. Companies that make hardware for semiconductor manufacturing (e.g. AMAT) or the software for semiconductor manufacturing (any of the EDA software companies). I do not understand these companies.

Design companies

As far as stock performance goes, the companies that are #1 in market share or the ones that will become #1 tend to do the best. Being #1 is a huge profitability advantage as R&D costs are scaled over a greater number of units.

Some types of hardware are incredibly hard for competitors to break into. Xilinx and Altera have been the top companies in their FPGA markets (usually 90% market share combined) and held off companies such as Intel. Because it is very expensive to design FPGAs, the quality of the manufacturer's design software is very important. In general, good software tends to be difficult to displace. Similarly, the discrete graphics (a standalone graphics chip that only does graphics) market is difficult to break into as graphics involves very complicated hardware and software drivers. I think of design companies as enjoying an intellectual property moat. However, this type of moat isn't that durable as another company can develop even better intellectual property. While this occurs rarely (the #1 and #2 companies in tech usually kill off a very large number of competitors to reach their position), it does happen.

Changes in the technology industry tends to happen very fast as technology scales very easily. There are some industries where change occurs more slowly since customers are entrenched in their current platform and switching costs are high. Mainframe computers (e.g. IBM) and networking (e.g. Cisco) may be like this.

Manufacturers

Two key factors in semiconductor manufacturing are (1) process size and (2) process technology. A smaller process size allows more transistors to be crammed onto a piece of silicon. Suppose that the total number of transistors stay the same. A smaller process size decreases costs since more chips can be created out of the same silicon wafer. It also decreases power consumption since all the circuits are packed more densely (the shorter wires require less power).

There can also be improvements in the actual transistors themselves and/or the materials used in manufacturing. Two major innovations are high-k dielectric materials / metal gates and finFET transistors (Intel calls their variation Tri-Gate). These improvements lower power consumption and/or improve speed (there are always tradeoffs that can be made between power and speed). Manufacturers may also have variations on their manufacturing process that can make tradeoffs between power and speed.

The size of the silicon wafers is another factor. Larger wafers are more challenging from a technology standpoint and require higher capital expenditures. However, they lower per unit costs.

Historically, semiconductor manufacturing hasn't always been a great business for all the companies involved. There is a technology treadmill as companies have to continually invest in the latest technology to bring their costs down. Without constant reinvestment they will be left behind. There are economies of scale that entice companies into expanding capacity and give the #1 market share leader an advantage. Sometimes the semiconductor manufacturing industry will experience intense price competition and times of oversupply.

Vertically integrated companies

The trend of the semiconductor industry has been moving away from vertical integration. In the past when mainframes dominated the computing industry, all companies designed and made their own silicon. Nowadays, many semiconductor design companies are "fabless" and outsource their manufacturing to contract fab companies like TSMC. The capital costs needed to create a new cutting-edge manufacturing plant has continually gone up and is somewhere around $5-$10B currently. Many vertically integrated companies are selling off their manufacturing units or entering into alliances since they do not have the capital needed to keep up with the technology treadmill.

There may or may not be small advantages or disadvantages to vertical integration. There are likely small efficiencies from vertical integration. For example, Intel carefully schedules its design projects and manufacturing investments so that all of its fabs are at high utilization rates. In practice, Intel currently has some excess capacity at its cutting-edge 22nm fabs (which produce CPUs cheaper and better than its older fabs). Meanwhile, its competitors' best fabs are at 28nm (without finFET transistors) and their customers desperately want higher capacity at the 28nm fabs.

In terms of the big picture, I believe that vertical integration may be mostly irrelevant. It probably isn't a huge advantage or disadvantage.

Other semiconductor manufacturers

Some companies such as Texas Instruments make analog semiconductors. This business has different economics than digital semiconductors as it isn't about constantly doubling the number of transistors on the chip.

Industry trends

Moore's Law

In the past, performance has roughly doubled every 18-24 months. The exponential rise in performance is slowing down for many markets as we are running into the laws of physics. Eventually the dramatic improvements in semiconductors will slow down to a trickle as we butt against fundamental laws of physics. The heat problem has already forced CPU manufacturers to add more cores instead of continuing to improve single-threaded performance at rates similar to the past. As transistors get down to the size of atoms there are problems such as quantum tunneling.

I'm not sure what will happen when Moore's Law slows down to a trickle. Some companies like Intel enjoy a premium valuation because they are able to drive dramatic increases in performance year after year. Their margins may get crushed when they can no longer continue to deliver.

System on a chip (SoC)

The industry trend has been towards consolidating multiple chips onto a single system on a chip. This lowers cost as long as the overall SoC isn't too large. This trend can create problems for the design companies whose designs aren't chosen to be on SoCs.

The investment challenge

Understanding the market and the technology

Sometimes this can be a challenge as journalists are often wrong. Some of them have a poor technical understanding of their subject (usually because they have worked in journalism but never in the industry they write about). Sometimes journalists hop onto a bandwagon that turns out to be dubious (e.g. the Y2K scare). Nobody is going to get a Pulitzer for explaining why

Y2K is irrelevant or how other journalists are wrong. *You need to do your own research and filter out the noise*.

Talking to industry participants directly may be helpful. But that is not something that I do. Sometimes industry participants will have blogs or they will make comments on news websites for their trade(e.g. eetimes.com).

Most semiconductor industries are large enough that you can find a lot of information about that industry on the Internet. You can find a lot of technical information on how the products work and how they are built.

The correct multiple

Because market share can change very quickly, I believe that technology companies with dominant market share deserve a lower P/E multiple than those in other industries. If they lose their #1 spot, they will not be able to harvest much profits out of whatever is left in their business. Of course, not all technology markets are like this. Mainframe companies are still profitable because it is so costly for their customers to leave them.

Conversely, if technology companies can quickly gain market share, I would think that potential future market share leaders deserve a higher multiple than companies in other industries. However, this type of investing could conceivably get one into trouble. Mentally, it is easy to get overoptimistic or greedy or to engage in momentum investing.

Regardless of whether you are investing in the current market leader or a potential future market leader, it is important to be able to predict who will be the market leader several years from now. This is difficult to do with a margin of safety.

Spotting the winners and the losers- my take

Among semiconductor manufacturers, the company that is #1 in market share will likely make almost all the money. Unlike other industries, being #2 may not be good enough. In CPUs, Intel has made enormous profits while AMD still has negative retained earnings.

On the design side, it can be difficult to predict who the market leader will be in the future. If we go back in time, it is obvious that IBM underestimated the rise of the personal computer. It invented the IBM-PC yet failed to capitalize on its invention. In hindsight, it gave away the crown jewels (the operating system and CPU design/manufacturing). IBM is run by some extremely smart people who failed to predict the future. I don’t think

that investors can expect to do a much better job of predicting the future. It's not just IBM. Back then, Microsoft thought that the smart TV was the future (e.g. Bill Gates wanted to buy John Malone's Liberty), many people thought that RISC would always rule in high-performance computing, etc. etc.

Brief comments on semiconductor markets

Desktops/laptops

It is likely that Intel will continue to dominate due to its manufacturing advantage over AMD. The overall market will likely continue to grow slowly as emerging economies increase their adoption of PCs. The average selling price of CPUs could decline somewhat as CPUs are increasingly becoming good enough and newer processors aren't really getting faster for desktop usage (desktop performance depends mostly on single-threaded performance, which has stalled).

Discrete graphics

Nvidia and ATI/AMD will continue to see the low-end of the discrete graphics market get eaten away by integrated graphics chips from AMD and Intel.

Some of this loss will be offset by increasing usage of general purpose GPUs, but the GPGPU market may only be a $1B/year market in revenue. I do not see discrete graphics as being a growth market.

Smartphones

The software side to smartphones is very important as it makes a huge difference between purchasing an Apple phone (Apple designs its own SoCs), an Android phone (currently almost all are powered by ARM SoCs), or another phone. I am not sure which software ecosystem will win though I would lean towards the company with the greatest market share (Android). On the hardware side, I think that Intel will eventually dominate though it is not a sure thing. The smartphone market may see its huge growth continue as there are "killer apps" in maps, GPS, social networking, and web browsing. I think that eventually almost everybody will own a smartphone much like PCs.

Tablets

Like smartphones, I am not sure which software ecosystem will be the winner (Android, iOS, Windows 8, etc.). I do not think that tablets will replace/cannibalize the PC as they are mostly used for reading (with light

typing) and watching movies. I don't see adoption rates for tablets being anywhere as high as smartphones and PCs.

On the hardware side, I would pay close attention to Microsoft's Surface product as it is somewhere between a tablet and a laptop/ultrabook. It may be an indicator for how the ARM versus Intel/x86 battles will play out in other markets.

Servers

I think that Intel will continue its dominant market share. Intel and AMD combined will continue to take share from other vendors. Intel's Centerton and AMD's Seamicro will go head to head in the wimpy core niche. I'm not sure that ARM chips will gain much traction.

HPC, Supercomputing

This is its own esoteric market (and a fairly small one). When it comes to high-performance computing, cost goes up exponentially for increased performance since performance is difficult to scale by simply adding more hardware. The trend away from RISC-based CPUs is likely to continue.

Memory

Historically not a great business. I wouldn't want to go long these stocks. While the flash memory market will probably continue to grow and many consumers will gravitate towards flash/solid state drives in their computers over traditional hard drives, the manufacturers of flash memory may not benefit from this trend.

Contract fab

TSMC is currently the #1 player and will probably make the most money in the contract fabrication market. I wouldn't really want to own the smaller contract fab companies. Fortunately for TSMC, Intel is not entering the contract fab business in a meaningful way. Unfortunately for TSMC, Intel will compete directly with the smartphone SoC customers that are driving TSMC's growth. There is a small possibility that TSMC will one day eclipse Intel as the world's largest semiconductor manufacturer.

LED lighting

The growth of LED lighting will likely continue for a long time. However, the LED manufacturers may only make small lumpy profits. LED lighting is mostly a commodity business for the semiconductor manufacturers.

Semiconductor Production - Design and Fabrication

Introduction

The small but mighty semiconductor has become an essential part of our high-tech world. Commonly called integrated circuits (ICs) or microchips, semiconductors are used in an ever-growing number of consumer, commercial, and industrial products. A very brief sampling of semiconductor uses includes:

- Personal electronic devices such as computers and tablets, mobile phones, and smart watches
- Household items such as televisions, appliances, LED light bulbs, and heating/cooling equipment
- Commercial and industrial products such as lasers, optical sensors, solar batteries, medical diagnostic equipment, traffic lights, and industrial machinery
  The majority of semiconductor demand is driven by products purchased by customers

Table 1. Percent of Semiconductor Demand by End Use, 2019.[1]

Communications	33.0%
PC/Computer	28.5%
Industrial	11.9%
Consumer Electronics	13.3%
Automotive	12.2%
Government	1.3% (includes military)

All of these diverse semiconductor applications share a common thread: the need for electrical properties specific to the application. A semiconductor is a material that has an intermediate level of electrical conductivity, hence the “semi” prefix. The material is composed of either a single element, typically silicon, or a combination of elements, such as gallium arsenide (GaAs), indium phosphide (InP), and a handful of others.

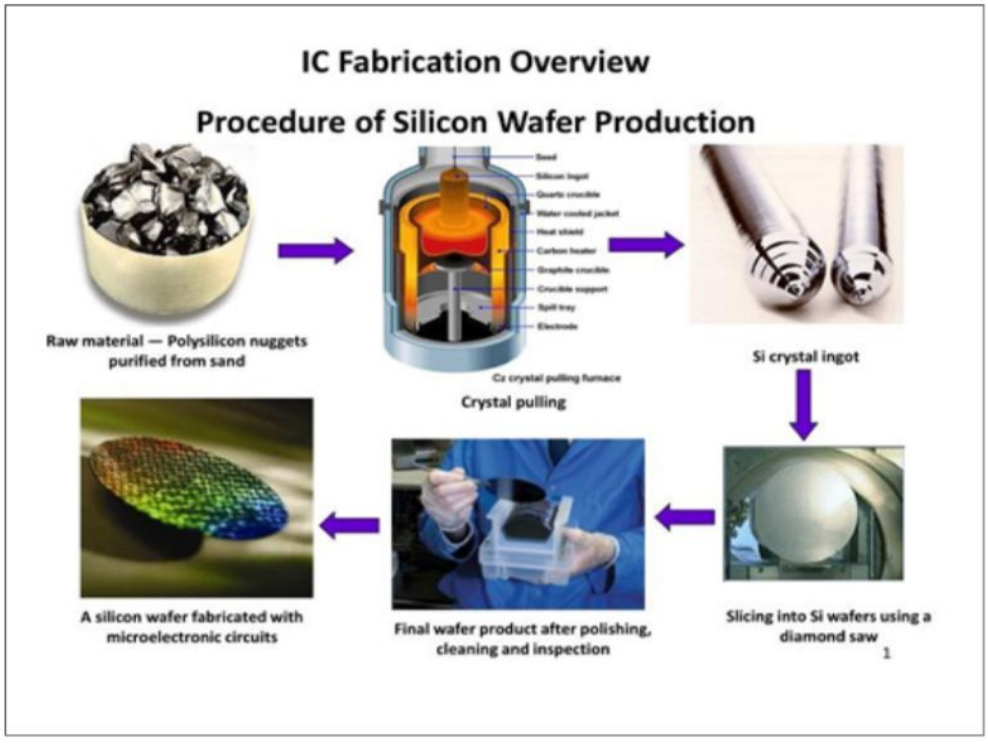
The substance most frequently used in semiconductors is the element silicon. Silicon comprises one-quarter of Earth’s crust, so it is an abundant resource. It is found in soil, sand, and rockin compound with oxygen,

aluminum, and magnesium. For production use, the silicon must be extracted from the compounds and purified to 99.999999999%.

Small amounts of impurities can then be added to change the material's conductivity. This process is called "doping" and can greatly increase the semiconductor's conductivity. Silicon's conductivity also changes based on the ambient temperature, with higher temperatures resulting in higher conductivity.

The great diversity of semiconductor end uses hints at the magnitude of impact the industry has on the global economy. Worldwide semiconductor sales were USD $412.3 billion in 2019. Global semiconductor industry sales are forecast to reach USD $433 billion in 2020.

Global sales of semiconductors were USD $34.4 billion for April 2020, which is a 1.2 percent decrease from March 2020 sales, but a 6.1 percent increase over April 2019 sales. These early 2020 sales indicate minimal impact so far from the novel coronavirus pandemic.


IC Fabrication Overview
Procedure of Silicon Wafer Production
Raw material — Polysilicon nuggets purified from sand
Cz crystal pulling furnace
Crystal pulling
Si crystal ingot
Slicing into Si wafers using a diamond saw
Final wafer product after polishing, cleaning and inspection
A silicon wafer fabricated with microelectronic circuits

The buyers of semiconductors for electronic equipment manufacturing are distributed around the globe, with the Asia Pacific region purchasing the greatest share:[1]

- Asia Pacific 62.5% (China 35.0%)
- Americas 19.1%

- Europe 9.7%
- Japan 8.7%

Semiconductor Production

Semiconductor production has two primary phases: design and fabrication. Companies that focus solely on design are referred to as fabless firms. Companies that focus only on fabrication are called foundries. Companies that do both the design and the fabrication are called Integrated Device Manufacturers (IDMs).

An overview of the semiconductor production process includes:

Raw Material Processing

- Silicon extraction from raw material
- Purification
- Cylindrical ingot formation, from one to nearly 18 inches (450mm) in diameter, up to 200 pounds each

Research and Development (R&D)

• Semiconductor design
• Process engineering
• Raw and fabrication materials selection • Quality control (QC) program design

Blank Wafer Production

• Ingots are sliced into 1mm-thick discs or “blank wafers” • Wafer diameter is adjusted if needed

Wafer Processing

- Multiple layers of transistors and wiring are formed on the wafer surface in an iterative process
- Steps include cleaning, oxidation-diffusion, deposition, photoresist patterning, etching, ion implantation

Wafer Cutting

• Wafer is cut into individual semiconductor units called dies

• Semiconductor chip packaging
• Each finished chip is attached to and encased in protective housing

These main steps are composed of 400 to 600 detailed steps that are typically completed over one to two months.

Challenges

The semiconductor industry has specific needs and faces unique challenges for successful and efficient production.

Detecting Ultra-trace Impurity Levels

Consumers continue to drive the demand for electronic devices that are smaller and lighter without sacrificing speed or reliability. That demand translates to a similar need for smaller and lighter semiconductors that are fast and reliable. The challenge facing fabricators is that the smaller the semiconductor, the more vulnerable it is to interference by chemical and particulate contaminants.

Semiconductor manufacturers need the ability to detect ultra- trace levels of contaminants throughout the fabricating process. Detecting chemical contaminants at the parts per trillion (ppt) level is no longer adequate — parts per quadrillion (ppq) detection limits must now be achieved. Particulates detection must reach nanoparticle size or smaller.

The R&D team must define the purity levels required for each material used in wafer fabrication and packaging:

- Silicon ingots and supplied blank wafers
- Ultrapure water
- Fine chemicals such as acids, bases, solvents
- Inert and specialty gases
- Circuit-building materials such as photoresist material, sputter target, CMP slurry

Packaging materials such as polymers, resins, dyes, solder, molding compounds, and die attachment materials R&D identifies the analytical instruments that can achieve the ultra-low detection limits needed for the potential impurities of each material. Sampling and analysis workflows are

developed and tested and, once confirmed, implemented for materials receiving and in-process testing.

Maintaining Production Efficiency

There are many opportunities for contaminants or physical defects to be introduced to the wafers as they move through the fabrication process. Such problems can decrease production efficiency or, even worse, cause production delays or product failure. It is crucial, therefore, that a rigorous process QC program be developed, implemented, and maintained. The goal of the program is to catch any problems as early in the workflow as possible to minimize wasted time and materials downstream from the problem.

The R&D team sets the downstream process standards and integrates them into the production workflow design. The process control manager collaborates with the R&D team during design and then implements and monitors the QC program. Critical monitoring points, materials, and parameters in the production process include:

Blank Wafer Production

• Check for physical deformities and residual particulates after ingot slicing and disc polishing

Clean Room Air

- Airborne molecular contaminants (AMCs) such as volatile and semi-volatile organic compounds (VOCs, SVOCs), metals, acids and bases, and anions
- Airborne particulates
- Air quality parameters such as temperature and humidity

Ultrapure Water

• Contaminants such as anions and cations, silicates, VOCs and SVOCs, organic acids, metals, and total organic carbon (TOC)

Circuit Formation Materials

• Organic and inorganic molecules, ions, acids and bases

To be fully effective at maintaining production efficiency, in-process QC monitoring must be nearly continuous and provide real-time identification of contaminants or specification failures. A high degree of automation minimizes error rates due to manual sampling, and online integration of the monitoring network provides fast turnaround and prompt data reporting.

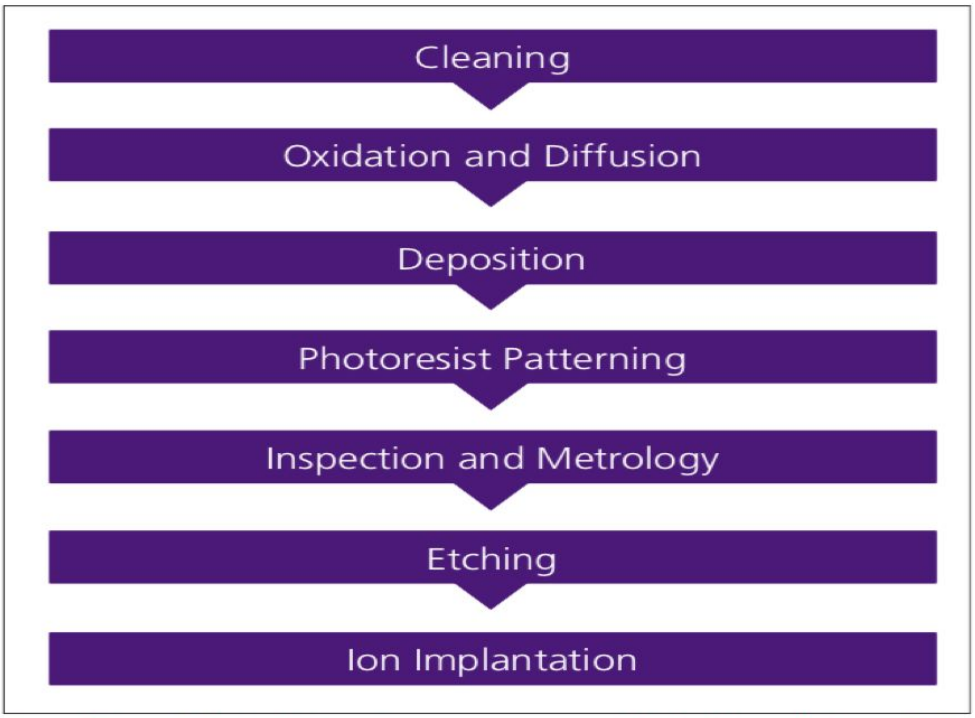


Figure 2. Steps of the circuit formation process are repeated to build a multi-layered IC.

Regulatory Compliance

Semiconductor manufacturers need to maintain compliance with national, state, and local regulatory requirements. A few nearly universal compliance requirements are considered here.

Permitting

A facility that uses materials that are classified as hazardous will require a permit from national, state, and/or local regulatory agencies to obtain, store, and use those materials. The permit stipulates the types and amounts of materials the facility can obtain, store, and otherwise use in their operations. It also defines the monitoring, record-keeping, and reporting requirements to maintain the permit.

Air permitting is also required for semiconductor production operations. The requirements of the permit will depend on the content of the air emissions

and the location of the facility. Air permits stipulate the monitoring, record-keeping, and reporting requirements to maintain the permit.

Employee Health and Safety

Some of the chemicals used in semiconductor production have the potential to release VOCs, SVOCs, and particulate matter to the facility's indoor air. Fabricators need exposure prevention protocols and monitoring programs to confirm compliance with regulatory limits designed to protect employee health.

A few practical steps that can move a facility toward these goals are:

- Improving process controls to reduce waste generation and air emissions. This can also increase production efficiency and control costs.

- Using R&D efforts to minimize use of potentially toxic materials in the production process and in the final product. This can reduce costs for waste disposal and the need for special permits or restrictive permit conditions.

- Using R&D efforts to increase the recyclability of electronic waste components. This can improve operational sustainability.

A stormwater pollution prevention plan may be required, depending on the extent of outside storage or operations
at the facility. The plan includes sampling and analysis procedures for stormwater discharges, remedial action plans, and record-keeping and reporting procedures.

Trends

There are numerous trends developing in semiconductor design, production, and use. Some have been developing gradually, others are advancing more quickly. The following are a few of the more commonly discussed trends.

Smaller ICs: R&D efforts continue at breakneck pace to further reduce the size of semiconductors. The industry has come a long way from 10 µm technology of the early 1970s to today's 7 nm chips, and industry leaders have even smaller chips in their sights: 5 nm, 3 nm, and beyond. Currently, 7 nm ICs are commonly used, 5 nm ICs are in production, and 3 nm ICs are under development.

Two important goals for 3 nm and smaller chips are to increase performance while decreasing energy use. R&D teams are looking to achieve these advances, in part, by transitioning from finFET to GAAFET technology. As chips reach the 3 nm and smaller sizes, fabricators will also need new equipment and methodologies for lithography, deposition, etching, and QC analytics.[3,4]

Fabless Designers + Independent Foundries: The trend toward more fabless chip design companies continues, and increasing numbers of technology companies are designing their own chips in-house. These trends are driven by the growing need for more specialized, application-specific chips designed for optimization of company-specific software and algorithms.

Some of the components of an effective health and safety program include:

• Personal protective equipment (PPE) requirements • Target parameters to be monitored
• Sampling and analysis schedule and SOPs
• Analytical sensitivity requirements

• Remedial action alternatives
• Regulatory reporting requirements, schedule, and means • Record keeping practices
• Other regulatory-specific requirements

A thorough, well-designed health and safety program promotes employee health and safety and helps the company avoid costly regulatory penalties.

Waste Management

Process wastewater and other process wastes are generated by manufacturing facilities of all types. The contents of these and other waste streams produced by semiconductor fabricators depend on the materials and processes used at the facility.

Process wastewater discharge to a treatment facility requires a permit and periodic sampling and analysis. The treatment facility will set the parameters for testing, content limitations, and reporting.

Other process wastes may include off-specification or contaminated materials. Characterization, storage, and transport of the wastes must comply with national, state,
and local requirements. A special permit may be required if any wastes are classified as hazardous. The waste disposal or treatment facility will require

analytical data on the content of each unique waste stream to ensure their acceptance of the waste complies with the terms of their operating permit.

Minimizing Environmental Impacts

Semiconductor producers, like all manufacturers, must consider the environmental impacts of their operations. In addition to meeting regulatory requirements for emissions and waste disposal, attention to a facility's environmental impacts can help control costs and increase the operational sustainability.

The fabless design-only and in-house design trends are, in turn, enhancing the need for and success of independent semiconductor foundries. Global expenditures for new foundries are forecast to be USD 50 billion over the next few years. It will be interesting to see how much of the foundry growth is invested in independent foundries.[5,6,7]

Artificial Intelligence (AI): The amount of data processed by AI systems is still increasing rapidly. The semiconductor industry continues to develop new algorithmic-specific chips that provide the processing speed needed for AI data.

Internet of Things (IoT): IoT systems produce tremendous amounts of data that are used to make real-time decisions.
The semiconductor industry continues to increase their R&D of new chip architectures, materials, and silicon photonics that will enhance IoT data processing capabilities and stability.

Autonomous Vehicles (AVs): Semiconductors will continue to be a key driver in the successful development of fully autonomous vehicles.

Section: 5

Career Opportunities in Semiconductor Industry

Career Opportunity in Semiconductor Industry (Global)

Demand is increasing for engineers and related technical fields in the IC industry, but companies are struggling to find enough talent. The problem is even worse in hot new markets such as AI and 5G, where competition is fierce for experienced workers.

The talent shortfall starts with college graduates and professionals in the fields of science, technology, engineering and mathematics (STEM). STEM training spans multiple industries, but it’s a significant problem for semiconductor and equipment vendors. While a shortage of STEM workers will not stop a company’s day-to-day operations, it does affect their ability to fill key positions, replenish an aging workforce, and develop new products and technologies. Longer term, it can hamper the pace of growth for the whole industry, and it can have an impact on the competitiveness of entire countries or regions.

The talent shortfall isn’t a new phenomenon. For years, the IC industry has experienced a shortage of various engineering types, but the problem has gotten worse as companies embark on a hiring binge. In the fourth quarter of 2018, staff/talent shortages emerged as the top risk factor that organizations face globally, ahead of privacy/regulation and rate of change, according to a new survey from Gartner. Talent shortfalls are a concern across multiple sectors, such as financial, industrial and manufacturing, according to the survey.

The semiconductor industry is in the same boat. According to a recent survey from Deloitte and SEMI, some 82% of executives reported a shortage of qualified technical candidates. Breaking that down further, some 60% of companies say that electrical engineering jobs are the most difficult to fill,

followed by computer sciences/software engineering (35%), mechanical engineering (35%), computer systems/engineering (30%), and materials sciences/chemical engineering (30%), according to the survey.

Compounding the shortages is a shift toward new technologies and automation. For example, machine learning requires new skills, but there is a shortfall of experts here. In addition, automation in the manufacturing sector is increasing, which means companies either have to retrain workers or replace them.

This is a complicated, multi-layered subject, but it's clearly a big issue. Last year, the semiconductor industry had some 10,000 job openings that couldn't be filled fast enough, according to SEMI. "Is there a shortage of people, yes or no? There is only one answer—yes. It's big time," said Ajit Manocha, president and chief executive of SEMI.

There are several reasons for the shortfall. "Enrollment in STEM education has fallen, while demand for high-skilled tech workers has increased partly because of the extraordinary growth of popular consumer-facing companies like Facebook, Amazon, Google and NetFlix," Manocha said. "These companies have captured the imagination of high school and university students and drawn attention away from the semiconductor industry. They are hiring people left and right."

So the IC industry is competing for talent against companies with global brands and more appeal. Apple, Google, Facebook and others also offer attractive compensation packages. "This has become a big issue for the semiconductor industry in recruiting and retaining talent, making the competition for highly skilled workers much fiercer," Manocha said.

The IC industry is working on solutions to solve the problem. But for the foreseeable future, the situation will remain an issue with some serious implications. "The IC industry is expected to double in the next 10 years. Without the right workforce in place, the industry will not be able to capture the growth. It's not going to happen," he added.

Competing for talent

The IC industry is an engine for economic growth. It paves the way for new and innovative products, and employs thousands of people in all fields.

The work is becoming more challenging and specialized, though. Chip scaling is becoming more difficult and expensive at each node. At the same time, 5G, AI and autonomous driving require new chip architectures and improved reliability. All of that requires talent, some with different skill sets.

“Talent is a-top three or top-five problem facing this industry,” said Dan Durn, senior vice president and chief financial officer at Applied Materials, at a recent event. “Anything else on that list, if we get the right talent, is solvable.”

There are other issues. “The issue is keeping the semiconductor and equipment industry an interesting place to work, so that you have this constant stream of people to keep the business growing,” said Risto Puhakka, president of VLSI Research. “The issue is how you create a stream of talent. It’s not about one year. It’s really about how do I have decades of talent coming in at a steady stream.”

Solving the issue is easier said than done. For decades, the industry has issued numerous reports regarding shortages of engineers and scientists, particularly in the U.S. Many blame the problem on K-12 education, insufficient funding in the field, and waning interest. The same issues apply today.

There is also conflicting data about the subject, with a few saying the so-called “STEM crisis” is overblown. Some believe there are enough students in the pipeline, but they are not interested in STEM. This is particularly true in the United States, so for years, U.S. universities have recruited students from abroad to help fill up their science/engineering programs.

That has provided a large pool of talent, and a recruiting ground for hi-tech companies. Companies also recruit students in Asia and Europe. But there are some alarming trends unfolding here. In 2017, the number of foreign students enrolled at the graduate level in science/engineering at U.S. universities fell by 6%, according to the National Foundation for American Policy.

While STEM is on the decline in the West, others are making gains. China had 4.7 million STEM graduates in 2016, compared 2.6 million in India and 568,000 in the United States, according to the World Economic Forum.

These and other trends have implications regarding a nation’s competitiveness, as well as the rate of expansion by the semiconductor industry into new markets.

“The demand for those talented individuals is a lot broader now than in the past,” said Chris Richard, a principal of strategy and operations at Deloitte Consulting. “If you come out with one of these engineering hard science degrees, you not only have opportunities for those kinds of roles, but you have opportunities to write code at Google or become a product marketing person at Amazon.”

The problem is that there aren't enough of them to fill the jobs in all of these areas. "We are short on STEM graduates," Richard said. "It's a challenge across all industries in the country. Hence, there are discussions around visas and how do you get enough qualified people just to meet the gap."

This is especially true in the IC and equipment industries, where vendors face various challenges to hire qualified technical talent. "The industry's workforce development challenge is rooted in four areas: 1) a shortage of students pursuing a STEM education; 2) lack of awareness of the industry and its vital importance in our everyday lives; 3) talent recruitment and retention issues partly because of the big, wildly popular consumer-facing companies; and 4) more restrictive immigration policies," SEMI's Manocha said.

Besides the STEM issues, the problem starts with the recruiting process. Semiconductor companies lack brand awareness, which makes it difficult to compete for talent against companies like Apple, Google and Facebook. According to the Deloitte-SEMI survey, Intel is the only IC company listed among the top 15 organizations in terms of brand awareness.

That's just part of the problem. Job candidates see the IC industry as a mature business that has undergone considerable consolidation. In addition, layoffs are common during downturns. For these and other reasons, retaining professionals is difficult.

"We are struggling to overcome a huge shortage of skilled workers, but at the same time our industry is growing," Manocha said. "Another issue is the aging semiconductor workforce. Longtime workers with deep knowledge in their fields bring tremendous specialized value to the industry across many disciplines. Replacing these highly skilled workers as they retire places even more pressure on the industry to build and maintain its talent pipeline."

Wanted: EEs, AI experts

It's not all doom and gloom. In the U.S., undergraduate degrees awarded in all engineering fields reached a 10-year high with 124,477 in 2017, up 10% over 2016, according to the American Society for Engineering Education (ASEE).

Mechanical engineering topped the list, followed by computer science and electrical engineering, according to the ASEE. The list also includes civil, petroleum and other engineering types. Master degrees were up slightly, while doctoral degrees fell.

Still, companies face the same problem. "There is a shortage of basically every type of engineer. There are so many new products coming out even

outside of the AI space. You have 5G and a number of other technologies," said Dave Fick, CTO of Mythic, an AI chip startup. "It seems like every week we hear about a new startup or a design center. Those, of course, are trying to hire lots of people, so there is tremendous competition for talent."

The same is true for software. "There is definitely a shortage of good software engineers in the world," said Aki Fujimura, chief executive of D2S. "There are by now plenty of people who can program. But that's different from professional software engineering. And that's different from computer science, which is a more academic discipline."

Competition for STEM workers is even more fierce in machine learning, which is used in nearly all industries. But organizations face some challenges to deploy it on a wider scale. According to a survey from Forrester, more than 50% of organizations lack the skills to deploy AI/ML/DL hardware.

"There is a shortage of deep learning experts. There is so much competition for strong software engineers, particularly those with iterative optimization experience from any discipline. They are highly sought, creating a void," Fujimura said.

Then, once you find experts, there are other issues—supply and demand tend to dictate the salary requirements. "For deep learning software engineers, one of the issues is the spike in compensation for those with experience and talent," he said. "As a management remedy, we need to hire a few (expensive) deep learning engineers to enable and train the existing software and other engineers in deep learning. Therefore, the faster we can train our own staff in deep learning techniques, the better. But when they do get trained, they will be highly sought after, even more than now. As every company goes through this, eventually supply and demand will even out. But in the meantime, there will be temporary insanity in competition for talent."

Manufacturing issues

In the manufacturing sector, meanwhile, semiconductor companies, foundries and equipment vendors face these and other issues.

Foundry vendors manufacture chips for other companies. At a given company, there are various job openings, including device design, big data, process/integration and yield analysis.

"Along with other industries, at GlobalFoundries, we definitely experience a supply and demand gap as it relates to STEM educated professionals," said Steve West, head of talent acquisition and human resource operations at

GlobalFoundries. “In some markets, our name recognition may not be as immediate as some of our competitors with well-known consumer brands. However, this is changing for us the more we recruit, and especially on college campuses.”

Another issue is that a large percentage of the foundry manufacturing base is concentrated in Asia. Europe and the U.S. have some fabs, but this limits the opportunities for some. “At GlobalFoundries, we find that when it comes to attracting global talent, we have an advantage with our geographic footprint, which includes locations in traditional markets in Europe and Asia, as well as a strong presence in the northeastern U.S.,” West said.

The semiconductor equipment industry, meanwhile, has its own needs. Equipment vendors develop systems, which in turn make the chips.

“We believe there is a shortage of talent, particularly for students and experienced professionals with backgrounds in computer science, machine learning and artificial intelligence,” said Cheryl Gee, director of talent acquisition at KLA. “We find it most difficult to hire algorithm experts, mechanical, optical, research scientists and applications engineers at the mid- to senior- engineering levels in Silicon Valley.”

KLA specializes in inspection/metrology equipment, although the requirements go well beyond hardware. “KLA’s historical competition came from other companies in the semiconductor market. Today, KLA faces competition from companies like Google, Apple, Facebook and startups working on autonomous driving and IoT,” Gee said. “Artificial intelligence and machine learning are integral to many companies irrespective of industry. Although many of our engineers write software and invent new algorithms, most candidates think of us as a hardware company, not as a place for software engineering careers.”

KLA and others have their headquarters in or around Silicon Valley, so it’s sometimes difficult to recruit candidates to move to this area due to the price-prohibitive real estate market, according to Gee.

Others face similar challenges, although each company is different. “Veeco’s technology goes beyond front-end semi and lithography into compound semiconductors. So, we also look for the best and brightest in the optics and photonics arena as well as materials experts,” said Brenden Wright, head of global talent acquisition at Veeco. “There is a shortage of talent across all business functional areas, but even more so in the highly technical areas like marketing, engineering (electrical, mechanical, software, and systems), and technology/process development.”

That’s not the only issue. “Unemployment is at or near historic lows, making this a candidate’s market,” Wright said. “We see candidates now who often have multiple options from which to choose and sometimes this choice is not limited to SEMI companies, but span different industries.”

Searching for solutions

Clearly, companies face several challenges, but are there are no simple answers.

For years, though, the industry has devised new and different programs to reverse the trends. Among them:

- Reach out to STEM high school students, exposing them to the industry.
- Increase recruitment efforts at universities.
- Strengthen partnerships and R&D efforts with universities.
- Establish internships and co-ops.
- Improve branding programs.

SEMI is also active here. In 2001, SEMI launched High Tech U, a program designed to interest high-school students in the semiconductor field.

Recently, SEMI launched two new programs. One is to form partnerships with universities to tap STEM talent. The other is to establish ties with community colleges. For this, the idea is to devise workforce development programs for technicians, such as machinists, operators and tool maintenance personnel. On top of that, SEMI recently announced SEMI Works, a comprehensive program to attract, develop and retain the talent critical to the worldwide electronics industry’s continued innovation and growth.

Most agree the STEM education process starts in the early stages. “We recognize that, from a larger community standpoint, it is important to help build the pipeline to STEM careers and cultivate interest in the technology industry at an earlier age at the K-12 levels,” said Audrey Charles, senior vice president of global human resources at Lam Research. “By supporting K-12 math and science education programs that better prepare students for high school and subsequent secondary education in math and science, there is an opportunity to foster more student interest in the challenging and rewarding careers that can be found in technology and engineering, both common and less common disciplines.”

It doesn’t stop there. “Opening our doors and exposing middle and high school students through onsite visits and encouraging employee mentoring opportunities also helps foster awareness and inspires today’s youth,” Charles said. “Additionally, within companies, it is important to implement

programs to challenge engineers beyond the work in their discipline, and provide opportunities for continuous learning."

Others agree. "Developing talent early is key to solving the talent shortage," Veeco's Wright said. "Internships, co-ops, and other early exposure opportunities provide potential talent with hands-on insight into just how impactful our industry is to the world of technology. Internally developing talent is always a good idea, and we should also do more of that. Branding and showcasing how our industry enables all this cool technology could (and should) attract new talent to our space and help keep those already here interested and engaged for the long term."

From there, the challenge is to recruit and retain talent. But will any of these or other programs work?

It's hard to quantify if any of the new or established programs have made any measurable gains. The industry will require new talent with fresh ideas, and attracting young people into a mature industry isn't easy.

Career Opportunity in Semiconductor Industry (India)

The Semiconductor/VLSI Industry in India is growing huge, no doubt. Almost all the top semiconductor and EDA corporations have operations in India. In India, we need more young engineers who can do Verification, Physical Design, STA, AMS, DFT, Testing, etc for the IP, SoC, and Chips. Most of the product companies [Chip & IP makers] outsource the above-mentioned activities, Verification, PD, etc., to their branch offices and services companies in India. Services companies hire a huge number of talented freshers who are experts in Verification, PD, DFT, etc because it helps them to save the cost in terms of salary expenses. At the same time, it helps freshers to utilize all kinds of opportunities in services space to grow as an experienced VLSI engineer and build their long-term career in the semiconductor industry.

Our engineers are well known for using all kinds of latest Verification languages and methodologies like SystemVerilog and UVM in the world. We are the best programmers and skilled engineers, whether it is VLSI design or software. So, it helps the global semiconductor industry to outsource all the activities, i.e. Verification, Physical Design, STA, AMS, DFT, Testing, PCB, System Design, etc to India.

Though there are a lot of opportunities and vacancies, the semiconductor industry hires only talented engineers and nobody hires an average engineer just for the sake of filling in the vacancies. The truth is, the industry struggles to fill in the vacancies. If you are truly passionate about chip design, then choose VLSI.

Skills Required to Build Career in Semiconductor Industry

Skills Required to build Career in Semiconductor Field:

There are significant no of jobs in semiconductor industry, specially people from electronics engineering background are very much interested to go in semiconductors industry, but they don’t know which path to take.

So, here are the few skills you should enhance if planning to go for semiconductors

- Semiconductor company looks for basic understanding of digital & analog circuit. A candidate needs to know how to solve basic digital design problems using multiplexer & Logical gates (AND, OR, XOR). How to design basic electronic circuit using combinatorial logic and Finite state machine (FSM).

- The candidate needs to have basic understanding of complementary metallic oxide semiconductor (CMOS) devices. What are the typical characteristics and properties of these devices? How to construct Flip Flops, gates using CMOS devices.

- The candidate should possess working knowledge of hardware design languages like VHDL, Verilog.

- Since designing a chip is a complex involved task, candidates having excellent track record in academics and technical projects are considered for the VLSI jobs.

- An experienced person needs to know the complete cycle for chip design & qualification. And How does each step in cycle impacts customer as shown in below picture.

- Extremely complex chips are the need of the hour. A candidate needs to know how best we can fit in more & more functionality to the chip, but still can reduce power and area of the silicon.

- The candidate needs to know, what the technology nodes industry is working with. What are the challenges with each technology node? What are the trade-offs associated with characteristic of CMOS devices at each node

- Since re-spinning a silicon is extremely costly affair, companies are working very hard to get zero defect silicon at first go. Candidates having in-depth knowledge of standard methodologies (like UVM, VMM) & tools (like FPGA prototyping) to make a zero defect chip are highly desirable at product companies.

- Semiconductor industry is very fast moving towards new technology and standards. The candidate needs to have basic understanding of few Industry-standard protocols like (Universal Serial Bus) USB, (Peripheral Component Interconnect – Express) PCIe etc.

- Technical innovation is the bread & butter for the industry. Candidates having patent & publications in renowned Journals like IEEE are most desired in a semiconductor company.

Typically a chip is designed & qualified at different RnD centre of a company; hence the person should be capable of working with multi-ethnic, multi-cultural environment within and outside company.

Section: 6

Resources for Semiconductor Businesses

Network Development Platforms and Information Resources in Semiconductor Field

Network Development and Information Resources in Semiconductor Field

To gain knowledge and learn new things on professional front or to simply stay connected with the industry updates, people usually keep coming to certain websites and profiles on social media platforms like Twitter, which share thousands of updates each day. This practice of subscribing to and following the industry networks can be as beneficial and interesting as the accounts and websites you choose to follow.

When it comes to semiconductor and electronic design industry, engineers, product architects, manufacturers, industry analysts, product managers and tech leads like you constantly want to get latest updates, find answers to common concerns and exchange knowledge. It is very important that the website or the network you follow provides valuable insights and

information that can enhance your opportunities as a professional in the semiconductor domain.

Hence, here we have compiled a list of 55 networks and profiles of the semiconductor and electronic design industry that you should be following or that should liven up your inbox (if you subscribe on their website) or Twitter feed (if you follow them on Twitter) in 2018. The list includes names of resources and networks from across the entire electronic and semiconductor industry, which is divided into following categories:

Insights, News & Updates

1. EDN Network

EDN Network is a great electronics platform for engineers that provide information, tools, courses, and professional connections to help you get your job done and get your ideas from concept to reality. It helps you avail information and updates from electronics industry leaders, manufacturers, technical service providers, and engineering novices to explore what's new and trending in the industry.

2. EE Times

EE Times is a global community, connecting electronics professionals and companies. It provides great insights from expert contributors and editors, community leaders and journalist of the electronics domain, which mainly consist of analog, SoC, prototyping, power management, wireless & networking, medical and industrial automation categories. It also welcomes contributions as guests if you want to share anything valuable in the electronics industry.

3. Embedded

Embedded.com is a one-stop resource for everything embedded systems developers and engineers need to do their job — from the latest products, tips, design, and coding trends, source codes, to practical design features, information, discussions, and industry happenings. Its special feature includes curate collections and archives to help you in deeper research. It also offers opportunities to contribute content, experiences, and ideas with the community. Do follow this if you want to learn and contribute in the embedded domain every day.

4. Evaluation Engineering

Evaluation Engineering provides in-depth technical insights to engineers, engineering managers, and corporate managers responsible for the quality of electronic products and systems. It mostly issues monthly magazine and digital edition, daily e-newsletters, product showcases, monthly special reports, in semiconductors, medical, communication, RF, microwave, and wireless applications.

5. Electronic Design

Electronic Design is a premier information source that provides comprehensive insights on the Electronics industry. The website of Electronic Design covers a full spectrum of information on technologies, from analog and power to embedded and automotive. Engineering professionals can follow Electronic Design to get critical content on rapid technological advances and their applications at the component, chip, board, and system levels.

6. IEEE Spectrum

IEEE Spectrum is the flagship magazine of the IEEE, which is the world's largest professional organization dedicated to engineering. It keeps over 400,000 members informed about major trends and developments in engineering and technology space through news and feature stories, blogs, videos, and professional resources.

7. ECNMag

ECN Magazine provides the most up-to-date information on electronic design, emerging technologies, and new products. It has been helping businesses and decision makers across topics like sensors, automotive, power, electronics, wireless, aerospace and many more. Follow it to get frequent and continuous updates on Electronic Design.

8. Tech Briefs

Tech Briefs provides an array of product reports on engineering innovation in key OEM markets. By following Tech Briefs, you can get information and ideas on topics like electronics, sensors, mechatronics, automotive engineering, and many more. Tech Briefs today is reaching over 600000 OEM engineers with product updates, newsletters, videos, e-sources, podcasts, webinars, and tech talks.

9. Electronic Products

If you want to keep a continuous tab on the electronics industry products, then this is the resource you should definitely follow. Electronics Products is dedicated to providing important updates, listings, tools, guides, videos and educational content related to electronics technology such as digital ICs, computer peripherals, lighting, optoelectronics, telecom, automotive, transportation and much more. It is also a great resource to learn about new electronic products and companies in the market.

10. Semico Research

Semico Research is a company providing valuable research reports and forecasts into the semiconductor markets. It hosts an extensive list of individual market research studies to help industry analysts take important decisions. The website of Semico Research also important events and news related to the Semiconductor industry.

11. EDACafe

EDACafe is again one of the best resources to learn about the latest insights and information on the semiconductor domain. Users can follow EDACafe to keep themselves abreast with the latest news and events in the semiconductor domain. Semiconductor professionals like you can also find latest jobs, articles, tutorials, and videos, which can help you enhance their career in the semiconductor engineering field.

12. Product Design & Development

It is a leading publication for design engineers to access latest trends, information, and insights related to product engineering, aerospace, industrial automation, consumer electronics and design tools. Follow Product Design & Development if you want to get product reviews, tips, best practices, news or guidance on your next product design.

13. Design World

Design World is the leading engineering resource serving design engineers, machine builders, and OEMs. If you are looking for industry experts covering product news and reviews, EE video, how-to articles, best practices in electronics design and electronic datasheet resources, you should definitely follow Design World.

14. Semiengineering

Semiengineering provides insights into designing, testing, verifying, integrating and manufacturing semiconductors. Developed by chip

architects, engineers, journalists, end users, industry organizations and standards bodies, Semiengineering is a great source of independent research, videos, news, and answers into the semiconductor industry.

15. Chip Design

Chip Design is a large network, providing technical insights and implementation options into electronic design and chip engineering systems. From technical papers and articles to news and events, Chip Design provides everything around topics like FPGA, MEMS, Automotive, IoT, Datacenter, and Connectivity.

16. SolidStateTechnology

Solid State Technology is a global resource for getting the latest insights, news, and information related to semiconductor manufacturing, integrated circuits, microelectronics, microstructure technologies, and processes. It also provides magazines which deliver in-depth business and technical analysis for semiconductor, MEMS, display, packaging, and LED manufacturing. Follow it to keep yourself abreast with the semiconductor industry updates.

17. ELE Times

ELE Times is another great resource to find trending information, news, and insights on technology and design. The website of ELE Times provides in-depth articles into categories like semiconductor, embedded, analog, automotive, IC’s system design, medical electronics and more to professionals and engineers looking for continuous updates into the electronic design field.

18. Design and Reuse

Design & Reuse is a leading network, providing value-added information on electronic virtual components, specifically IP (intellectual property) and SoC’s (systems-on-chips). The website of Design & Reuse provides daily updates to an average 70,000 absolute unique visitors. If you are looking to get updates, announcements, and news of IP/SoC domain, follow Design & Reuse.

19. Semiconductor Today

Semiconductor Today is a digital magazine for the compound semiconductor and advanced silicon industries. It is read and followed by thousands of engineers, executives, and manufacturers involved in the R&D of

semiconductors as well as silicon materials and devices. You can also find events and news related to semiconductor from the website of Semiconductor Today.

20. PowerElectronicsTech

Power Electronics is a perfect place to find important information on power components and systems. It provides expert insights and resources such as white papers, webinars, and stories on automotive, power management, high-frequency designs, mechanical design, and electronics procurement.

21. EECatalog:

EECatalog provides valuable product and tech information, covering the electronics industry. To get important updates, news and insights in areas like FPGA, SoC, Chip Design, System Design, Low Power, 8 Bit, Sensors & MEMS and more, you should definitely follow EECatalog.

22. DIGITIMES, Inc.

DIGITIMES is leading newspaper network that provides daily coverage on semiconductor, electronics and computer industries to industry professionals, investment analysts and media around the world. It specializes in providing content around global high-tech trends that help companies create a win-win business relationship. The website of DIGITIMES serves content to over 150000 visitors each month, 50% of which are based in North America region.

23. EIN Semiconductor

EIN Semiconductor is a part of the EIN Newsdesk (a leading media house) that helps you get breaking news and updates in the semiconductor industry. It works as a news monitoring service that identifies published news about semiconductors from thousands of sources for journalists and industry professionals. Don’t forget to follow it if you are looking for continuous updates and news on the Semiconductor industry happenings.

24. Compound Semiconductor

Compound Semiconductor is a great platform that provides news, analysis, opinion, information, and services for the worldwide Compound Semiconductor industry since 1995. It is a part of the Angel Business Communications that aims to feed the latest news to industry professionals and connect them to the industry trends.

Communities & Associations

25. SIA

SIA (Semiconductor Industry Association) is an alliance of semiconductor companies in the USA, working to manufacture the systems and products you use for work or communication, travel, entertainment, treat illness, and make new scientific discoveries. The network strengthens U.S. leadership of semiconductor manufacturing by providing research reports and resources as well as by working with key industry stakeholders to encourage policies and regulations that drive business and industry competition.

26. SEMI

SEMI is a global association of micro and nano-electronics that serves its members with programs, initiatives, events, and actions to advance business and worldwide market growth. It facilitates the development of the semiconductor industry by organizing regional trade events and conferences and fostering collaboration among members. In addition, SEMI also helps you explore diversified business opportunities and contribute to adjacent technology markets.

27. AnySilicon

AnySilicon is the best network to find, explore or contact any semiconductor service provider or IP vendor. It covers all domains right from ASIC design to production and IP Portal to help you find the best partner and solution to your requirements.

28. ESDAlliance

ESDAlliance, better known as Electronic System Design Alliance is an international association of companies providing goods and services throughout the semiconductor design ecosystem. It provides a great forum to address technical, marketing, economic and legislative issues in the electronic system design. It also acts as a networking hub for the industry and hosts educational and other events relevant to the industry and the community.

29. EEWeb

EEWeb is a great resource for electronic design engineers. It has a community of experts and members of the electronic design. It also lists a suite of free design, analysis and verification tools as well as components. Both experienced and novice electronic designers can access multiple articles, discussion threads, job openings, events, projects and technical communities by following EEWeb network.

30. Global Semi Alliance

Global Semi Alliance is a non-profit organization with over 400 members in the semiconductor ecosystem. It is a platform that provides global collaboration opportunities to semiconductor industry companies and professionals. It helps members to address common challenges across the intellectual property (IP), electronic design automation (EDA)/design, wafer manufacturing, test and packaging with a range of research, publications, and technical resources.

31. ChipEstimate

ChipEstimate is a community, comprising over 200 semiconductor design and verification IP suppliers. It helps the worldwide electronic and chip design professionals achieve success by providing opportunities to connect, find resources relevant to their profession and exchange insights and tools with IP partners and vendors.

32. ENGINEERINGcom

It is a leading community of over 1.5 million technical minds and professionals looking to solve problems and share knowledge in the engineering field. It lets you collaborate with experts and community members via messaging, whiteboards and partnerships. The site also lists jobs, articles, projects and useful resources and forums.

33. Ed Hall (SEMI)

Ed Hall (SEMI) is a part of SEMI, which is dedicated to providing market data and research reports covering semiconductor and HB-LED capital equipment, fabs foundries, and packaging. Since it provides important research and insights into different semiconductor markets, it helps you make important investments and strategic decisions.

Components Distributor Resources

34. Mouser Electronics

Mouser Electronics is an authorized distributor of semiconductors and electronic components for design engineers. Follow them to get updates related to semiconductors, embedded solutions, sensors, engineering tools, circuits, applications, electronics components, and tools.

37. Digi-Key Electronics

Digi-Key is dedicated to distributing worldwide electronic components. Since 1972, it has been committed to providing the broadest selection of in-stock electronic tools and products to aid engineers and manufacturers in the entire design process — prototype to production. Since Digi-Key is an authorized distributor for more than 50 industry-leading suppliers, you can rest assured of the authenticity and standardization.

38. element14

element14 is another high-service distributor of technology products, tools, and services for the electronic and system design professionals. It provides a broad range of solutions and delivery options, providing greater access to the product stock as well as stronger relationships with suppliers, meeting the needs of customers around the world. element14 also shares the latest news and inspiration in the electronic design domain.

39. Future Electronics

Future Electronics is again a worldwide leader in electronic components distribution. It provides advanced engineering/design capabilities and technical solutions to help device manufacturers build futuristic devices and develop supply chain solution. It also provides technical resources such as market reports, magazines and components library.

Expert’s Networks (owned by Experts)

40. SemiWiki

SemiWiki is an open forum for people involved with electronic devices and the semiconductor design. It is a great resource to read and explore observations, experiences, and opinions in the semiconductor industry.

Subscribers of SemiWiki can avail valuable insights from SemiWiki bloggers who are also leading industry professionals like Daniel Nenni, Daniel Payne, Eric Esteve, Bill Jewell, Scotten Jones, Mitch Heins, Tom Simon, Bernard Murphy, Robert Maire, Alex Tan, and Tom Dillinger. The portal also shares professional connections with companies like ARM, Cadence, Synopsys, Intel and many more.

41. eeNews

eeNews connects engineers with knowledge shared by experts, industry designers and vendors. Run by Peter Clarke, the website of eeNews is a great source to get the latest updates in the electronic design domain, including product reviews, research, expert advice, breaking news, product announcement and much more. You can also find new events, seminars, and exhibitions happening in the semiconductor industry.

42. SemiAccurate

SemiAccurate is a technology news site providing a wide range of resources and insights into the semiconductor industry, specifically on topics such as hardware reviews, security, theoretical technology and enterprise products. The website is owned by Charlie Demerjian (also the founder of Stone Arch Networking Services), who along with Thomas Ryan, Leo Yim and Copper create the technical insights and provide updates on SemiAccurate website.

43. Semiconductor Business Intelligence

Semiconductor Business Intelligence, owned by Claus Aasholm specializes in providing customized research reports, insights and facts in the semiconductor market. Using Big Data, dashboards and visual analytics as well as monitoring the financial results, it disseminates reliable data and information which help in taking the right decisions.

Companies

42. Intel

As everyone knows, Intel is the world’s second largest and second highest valued semiconductor chip maker and is the inventor of the microprocessors

and processors found in the personal computers. This powerhouse of engineering and technological excellence empowers diverse technology areas such as the cloud and the data center, the Internet of Things, memory and FPGAs.

43. Qualcomm

Qualcomm is a semiconductor and telecom equipment company that designs and markets wireless telecommunication products. It is considered as a leader in next-gen mobile technologies that are revolutionizing the smartphone market with 3G, 4G, and 5G technologies.

42. NVIDIA

NVIDIA is a company that designs graphics processing units (GPUs) for the gaming, cryptocurrency as well as the system on chip units (SoCs) for the mobile computing and automotive market. It pioneered supercharged computing and provides parallel computing to researchers and scientists. Today, NVIDIA is increasingly known as the AI computing company.

43. Texas Instruments

Texas Instruments is an analog and digital semiconductor IC design and manufacturing company. The company is constantly working to make cities smarter, cars safer, factories automated and bring to life connected wearable products with performance and power-efficient products.

46. ARM

ARM is a leading semiconductor IP company that is transforming everything — from smartphones to supercomputers, from medical instruments to agricultural sensors, and from base stations to servers with devices and connected technologies.

47. NXP

NXP is Nasdaq-100 technology company, enabling secure connections and infrastructure for a smarter world. It is driving innovation in the areas of connected cars, cyber security, portables & wearables, and the Internet of Things.

48. Arrow Electronics

Arrow Electronics is a company providing products, services and solutions for industrial and commercial usage of electronic components, and

enterprise computing solutions. The company offers specialized services and expertise across the product lifecycle, connecting people to the right technology at the right time.

49. AMD

AMD is an innovation company dealing in high-performance computing, graphics and visualization technologies, immersive platforms, and the datacenter. It also develops computer processors, motherboard chipsets, embedded processors and graphics processors, and related technologies for business and consumer markets.

50. Synopsys

Synopsys is a world leader in the EDA. It is at the forefront of advanced silicon chips technology for smarter and secured everything with world's most advanced tools for silicon chip design.

51. Analog Devices, Inc.

Analog Devices is a global leader in the design and manufacturing of analog, mixed-signal, and DSP integrated circuits.

52. Cadence

Cadence is leading global EDA company that provides the tools, expertise IP, and hardware required for the entire electronics design chain, from chip design to chip packaging to boards and to systems, enabling electronic design innovation.

53. On Semiconductor

On Semiconductor is a leading supplier of semiconductor-based solutions, offering a portfolio of power management, sensing, energy efficient connectivity, logic, analog, discrete, timing, and custom devices. The company's products help engineers solve their design challenges in automotive, communications, computing, consumer, industrial, medical, and aerospace/defense applications.

54. STMicroelectronics

STMicroelectronics is a world leader in providing the semiconductor solutions. Following them can help you get updates about their practices and activities in the semiconductor market.

55. eInfochips

Lastly, its eInfochips (because we can’t forget to include ourselves J), an Arrow company. It is a global technology firm, specializing in product engineering and software R&D services. It delivers solutions in silicon engineering, embedded systems, and software engineering field, providing assistance from concept to design and development to deployment and sustenance.

Do’s for Semiconductor Startups

In 2013, close to a quarter of all VC funding was directed towards internet companies. (Preqin, June 2013). If you were a VC, you’d probably do the same. Internet companies are more agile. They can easily change their

product, business model, and transform the entire company direction overnight. On top of that, the investment is a fraction of what's needed for a semiconductor startup and let's face it – Internet companies are a bit sexier.

With maskset prices only going up, raising money is not going to become any easier. So what are you options as a fabless startup? While we can't solve the funding challenge, here are a few tips that may help you limit your expenditures.

1. Collaborate with Foundries and Assembly Houses

As a new start up you must be a in a constant look for new competitive edge whether it's price or performance, power consumption, there is a lot to gain in the production phase as well. New technologies in packaging can reduce the total device cost and better collaboration with the foundry can give you better understanding on how to optimize your design for better performance.

On the other hand, assembly house and foundries are looking for new requirements in order to drive new products and technologies and without having direct contact to the market they are missing real-life demands to enable new features.

2. Partner with IDMs

While qualcomm, broadcom and other large IDMs are looking for getting more market share and beat competition – perhaps you can help them. By using IDMs distribution channels you can get closer to your customers and even more close to get some cash.

The tricky part is to find the IDM that needs your technology and needs it now. Try to connect to business development folk to see if your offering make sense for their sales strategy. There have been several start-up and IDMs engagement in the past that ended up in a happy marriage.

3. Find Great Semiconductor Suppliers

To lower the risk and reduce time to market, you need great partners. Use AnySilicon search tool to identify vendors that can support you quickly. Some suppliers offer very professional solutions and services together with creative business models that can help with reducing the upfront investment. A combination of technical and commercial engagement could be a key to your success and really value add for a small startup.

AnySilicon's directory is a good place to start when you are kicking off a new project. The number of vendors in the database is increasing daily and offer huge diversity, from ASIC design, wafer supply, package design to FIB services. Everything you would need to realize an ASIC.

4. Engage with Customers before you Start the Design

We have been involved in many semiconductor products for many years and seen big mistakes consistently repeated. One of the biggest mistakes is about product definition. Engineers and managers believe they know what customers want even without meeting them or talking to them.

In any company, and especially in hardware-based companies, where there is a lot of money involved with product re-definition – changing a product means money. For fabless companies adding a feature which is hardware-related (vs. software related) can cost a lot of money. Adding functionality into the silicon will consist of: design and verification of the ASIC, a new maskset, production test updates and sometimes changing the package type. This requires a huge capital investment and at least 6-12 months of delay

5. Think Vertical

There are many examples of fabless companies changing their business models and ending up selling a product instead of a chip. The motivation behind this step was mostly because they could not find any customers for their silicon — so they decided to design, build and sell the end-product themselves.

There are great examples of chip companies selling end products. SanDisk is one of them. We all know them as the USB-stick company, but actually

the core competence of the company is ASICs. The end product is different and obviously generate much more profit.

This means that Instead of selling chips, you may want to think vertical – can you sell an entire product based on your chip or perhaps a module?

6. Buy IPs, Don't develop them

Don't, please don't develop IP blocks, if they exist, buy them.

The three top places to go today are:

AnySilicon.com (we have IP listing since Jan-15)

www.chipestimate.com

www.design-reuse.com

Source: https://www.engineersgarage.com/featured/how-india-growing-semiconductor-sector/

How India is growing the semiconductor sector

According to research by MarketsAndMarkets, the Indian semiconductor market's worth is forecast at USD 32.35 Bn by 2025 — growing at a CAGR of 10.1 percent between 2018 and 2025. India is currently developing an electronics system design manufacturing (ESDM) industry, with a base of more than 120 units. About 2,000 chips are designed every year in India, per the Department of Electronics and Information Technology (DeitY), with more than 20,000 engineers working on different aspects of chip design and verification.

With the launch of Make in India, a government initiative for job creation and skill enhancement in 25 sectors of the economy, the ESDM industry is expected to benefit with investment proposals worth Rs 10,000 crore (USD 1.5 Bn) within the next couple of years.

The Indian government, in collaboration with the semiconductor sector, has increased its support of the ESDM industry. Initiatives outlined in the National Electronics policy and the National Telecom policy are now in the process of completion, including the Electronics Manufacturing Clusters (EMC), Preferential Market Access (PMA), and Modified Special Incentive Package Scheme (M-SIPS).

Sector subsidies

The government recently announced several subsidies and incentives for establishing electronics manufacturing companies in India. The goal is to achieve a higher degree of self-sufficiency in electronics in the country. According to one survey, the ESDM market is expected to grow from USD 76 Bn in 2013 to USD 400 Bn by 2020. The semiconductor market is also expected to grow, which means there will be a need to fill this manufacturing gap in the electronics arena.

The Indian government has granted 100 percent Foreign Direct Investment (FDI) as part of the automatic route in the ESDM sector. The FDI in electronic manufacturing reached an all-time high of Rs 1,23,000 crore (USD 18.34 Bn) in 2016 from about Rs 11,000 crore (USD 1.64 Bn) in 2014.

Additionally, India has signed an MoU with Singapore Semiconductor Industry Association (SSIA) to develop trade and technical collaboration between the two country's electronics and semiconductor industries.

Companies are now recognizing the potential of the sector in India and investing heavily in manufacturing. For example, Panasonic Corporation is incorporating a new plant in Haryana, which will produce refrigerators and build a research and development (R&D) center for appliances for the Indian market.

R&D opportunities

Numerous reports indicate that India is an ideal location for global R&D centers because of the skilled yet low-cost workforce compared to that found in the U.S. and Western European countries. India ranks third, globally, for its abundance of scientists and technicians.

Bangalore is quickly emerging as a hub for innovating start-ups in the semiconductor arena. The government's initiatives are supporting access to funds, training, and partnerships — including domestic and international market networks.

The state government of Karnataka is also working with the India Electronics and Semiconductor Association (IESA) to develop an ecosystem that fully supports the ESDM sector and semiconductor manufacturing throughout India.

Additionally, the Indian government is developing "electronics manufacturing clusters" throughout the country to offer world-class infrastructure and facilities. For example, it has received applications from

two consortia (Jaypee Group, IBM, TowerJazz and ST Microelectronics, HSMC) to establish a couple of semiconductor wafer fabrication units in Gujarat and Noida. The goal is to operate a 20-nm process node within two years of preliminary operations, reaching a capacity of at least 40,000 WSPM at a minimum of 300 mm.

Import challenges

The growth of digitalization and **r**ising disposable incomes in India are spurring consumer demand for electronics — and the need for local electronic production capacities. However, nearly 75 percent of consumer demand is met through imports.

India is strongly dependent on importing electronics hardware. The country's total electronics hardware production in 2014-15 was about USD 32.46 Bn, with domestic consumption at about USD 63.6 Bn, which means 58 percent of the feeding was completed with imports.

According to Assocham-NEC 2017, the increased demand for electronics is expected to leave the domestic production stagnant, which means an increase in imports of about USD 300 Bn by 2020. The need for electronic products in India is expected to reach USD 400 billion, growing at a CAGR of 41 percent by the year 2020. Domestic production is developing at a CAGR of 27 percent.

However, thanks to government subsidies and the manufacturing capabilities in India, the country has the potential to achieve a large degree of self-sufficiency in electronics.

Tools to Manage Semiconductor Business

Tools for Business Management

Why do you need small business tools and software?

Modern small business software and tools help small businesses operate more efficiently. Today's technology enables real-time delivery and deployment of information to give small businesses immediate, reliable, and secure access to company data and information whenever and wherever you need it.

However, in order for small businesses to scale, prioritizing and optimizing teamwork is essential. Small business software and tools can be used to conquer everyday tasks from tracking employee productivity and performance to people and money management to streamlining communication and collaboration.

What are the benefits of small business tools and software?

Running a small business is a team effort. Aligning team goals with business goals will help you prioritize your short and long-term needs before making a buying decision.

As remote work and virtual workplaces continue to evolve, small business software and tools can empower your entire organization to achieve results faster by keeping your work organized, your teams in sync, and your business thriving.

Communication

Communication software and tools bolster teamwork and boost productivity. When teams practice good communication habits, they foster contagious chemistry that can impact culture, collaboration, and productivity. Never miss a beat when you're always connected.

- Incentivizes meaningful conversations
- Ignites thoughtful dialogue
- Encourages deeper engagement
- Drives cohesive decision-making

Collaboration

Collaboration software and tools fuel every facet of your business. This is especially true for small businesses with remote teams. Modern

collaboration software empowers teams to work smarter together no matter where they are.

- Creates a network shareable knowledge
- Cross-functional ideas exchange
- Ecosystem of shared resources
- Team alignment and problem-solving

Productivity

Productivity software and tools help teams work smarter, not harder. Productivity tools can also have an invaluable impact on your overall performance by powering momentum and conquering procrastination.

- Create custom digital workflows
- Automate recurring processes
- Optimize teamwork and performance
- Divide and conquer projects, tasks, and to-dos

Marketing

Marketing software can make a good marketer *great* with powerful tools that provide intimate insights about customers that help produce qualified sales leads.

- Automate scheduling
- Build a website
- Impacts employee performance
- Organizes tasks and to-dos

Accounting

Modern accounting software and tools help you keep track of the money coming in and going out of your business—and you don’t need to be a financial guru to get started.

- Track revenue and expenses
- Handle taxes and payroll
- Generate custom reports
- Analyze and forecast finances

Operations Management

Operations management software helps monitor employee engagement and satisfaction, and establish quality control.

- Hire, onboard, and groom top talent
- Establish accountability and align goals
- Prioritize support and streamline feedback
- Build employee confidence and team morale

What are the best small business tools and software?

Choose from 50 small business tools and software to help run your business like a pro. Click on the categories below to jump to each section. This list has been updated as of Feb. 2020.

Communication Software for Small Businesses

Team Messaging
1. Flock
2. Slack

Video Conferencing
3. Flock
4. Zoom

Email
5. Gmail
6. Titan

Collaboration Software for Small Businesses

Project Management
8. Asana
9. Trello

File & Document Manager
9. Google Drive
10. Dropbox

Note-taking Apps
11. Todoist
12. Evernote

Productivity Software for Small Businesses

Workspace Organization
13. Shift
14. Station

Time Management

15. TimeDoctor
16. RescueTime

Process Automation
17. Zapier
18. Automate.io

Scheduling
19. Calendly
20. Doodle

Marketing Software for Small Businesses

CRM Apps
21. HubSpot
22. Zoho

Social Media Marketing
23. Buffer
24. Hootsuite

Email Marketing
25. Mailchimp
26. ConvertKit

Website Host
27. GoDaddy
28. Siteground

Website Builder
29. Wordpress
30. Wix

Design Tools
31. Adobe Creative Cloud
32. Canva

Accounting Software for Small Businesses

Bookkeeping
33. QuickBooks
34. FreshBooks

Payments
35. PayPal
36. Stripe

Invoicing
37. Xero
38. Wave

Tax Filing
39. TurboTax
40. H&R Block

Operations Software for Small Businesses

Customer Service
41. Zendesk
42. Help Scout

Contract Management
43. DocuSign
44. HelloSign

Performance Management
45. BambooHR
46. 15Five

Recruitment
47. LinkedIn Recruiter
48. AngelList

Learning and Development
49. LinkedIn Learning
50. General Assembly

Communication software and tools for small businesses

Team Messaging

Direct, one-on-one, and team messaging software has emerged as the primary means of small business communication with the ability to send and receive information, ideas, files, and more all in real-time. Messaging provides instant access to information email cannot.

1. Flock

We believe Flock is the best small business software for team communication because it's more than just a messenger: It's a business collaboration hub that helps you get more done, faster. Flock changes the way you connect with your team with direct and group messaging channels, video conferencing, secure file sharing, shared notes, company directories, custom team mailing lists, and more—all from a single app. Flock does everything your small business needs to communicate and collaborate effectively...and still so much more.

Plans
Basic: Free
Pro: $4.50 per user/mo.

2. Slack

Slack shares many of the features as Flock but it comes at a higher cost per user, per month. Compare **Flock vs. Slack**.

Plans
Basic: Free
Standard: $6.67 per user/mo.
Plus: $12.50 per user/mo.

Video Conferencing

Video conferencing software and tools give small businesses **the flexibility of communicating face-to-face from just about anywhere**—the home, the office, or a job site—across all devices. The right software and tools integrate screen-sharing, screen-recording, and video streaming capabilities that give SMBs powerful tools to conduct professional virtual meetings.

3. Flock

Video conferencing is essential for globally dispersed and remote teams. Flock gives small businesses the ability to host online meetings and webinars with video-conferencing software built right into the core messenger. Start a video call directly in a conversation channel and share your screen during a live stream or presentation. Flock video conferencing lets you communicate with anyone face-to-face and in real-time from anywhere.

Plans
Basic: Free

Pro: $4.50 per user/mo.

4. Zoom

Zoom is one of the more popular small business video conferencing apps on the market. Its free plan lets you host unlimited 1:1 meetings or group meetings of up to 100 participants with a 40-minute limit, and includes custom meeting IDs and screen-sharing capabilities in HD.

Plans
Basic: Free
Pro: $15 per host/mo.
Business: $20 per host/mo.

Email

Email is still the most widely used business communication tool. While email is not ideal for quick discussions or decisions, it does establish a thread for robust dialogue, specifically when communicating with multiple internal or external stakeholders. It’s absolutely vital for SMBs to have a professional email address that represents your business and your brand.

5. Gmail for G Suite

Gmail’s professional counterpart gives SMBs a customized email address and access to Google’s full suite of business products and admin tools that help consolidate and optimize your organization’s communication.

Plans
Free 14-day trial, then $6 per month

6. Titan

Titan is modern business email that means business. Get a professional email address to match your website's domain name without having to pay a bunch of money for a bundle of add-ons you don't need. Build your brand and your business on the back of Titan.

Plans
Free 30-day trial, then $1.50 per user/mo.

Collaboration software and tools for small businesses

Project Management

The primary purpose of project management tools is to track teamwork and optimize productivity. Small businesses rely on project management software and tools to ensure that teams carry a balanced workload and tasks get completed on time.

7. Asana

Asana is an essential small business tool that teams use to stay focused on the goals, projects, and daily tasks of a growing business. The ability to view all of your projects in calendar view, list view, or board view, and assign tasks with due dates to multiple stakeholders is a beautiful thing. Asana's aesthetically pleasing user interface and versatility are a few reasons why it's one of the more popular project management tools on the market.

Plans
Basic: Free
Premium: $11 per user/mo.
Business: $25 per user/mo.

8. Trello

Like Asana, Trello lets you work more collaboratively with boards, lists, and cards that help you to visually organize and prioritize team projects like a pro should. Small businesses use Trello for a lot—from product planning to content strategy to budgeting. There's not a whole lot that Trello can't do to improve the way your small business works and collaborates.

Plans
Basic: Free
Business: $10 per user/mo.

File & Document Manager

Data management and file-sharing systems are essential to small business operations and team collaboration. File sharing software backs up all of your important files and documents in the cloud and syncs them across all your devices—all the while keeping a record of relevant and shareable data accessible throughout the entire company.

9. Google Drive

Google Drive is the most popular cloud-based small business file management and sharing software, and it's absolutely free. You can create, store, and share all types of files from documents to slide presentations to spreadsheets to images and edit them collectively as a team in real-time. Google Drive even lets you sync your files across all your devices and share them publicly or privately with external stakeholders.

Plans
Basic: Free, 15GB
G Suite: $6 per month, 30GB
Google One: $2 per month, 100GB; $3 per month, 200GB; $10 per month, 2TB

10. Dropbox

Dropbox has long been known for its blazing-fast sync speeds ideal for larger, more unique file types often used by developers and designers. Plus, its best-in-class user experience and a plethora of add-ons like watermarking, tiered-admin roles, and file recovery give Dropbox the edge for product development and creative teams.

Plans
Individual Plus: $10 per month, 2TB

Individual Pro: $17 per month, 3TB
Teams Standard: $12.50 user/mo., 5TB**Teams Advanced:** $20 user/mo., Unlimited

Note-taking Apps

Note-taking tools ensure everyone on your team is fully engaged and on the same page—literally. Digital note-taking tools integrate across many productivity platforms and are the most resourceful way to keep all relevant information together and accessible. Attach notes to a message or email, or convert them into tasks or to-dos.

11. Todoist

Todoist keeps everything on your plate organized and accounted for. Get a clear overview of your workday and your schedule, and prioritize projects so you'll always know exactly what to work on next. Never lose track of an important task or to-do again.

Plans
Basic: Free
Premium: $3 per user/mo.

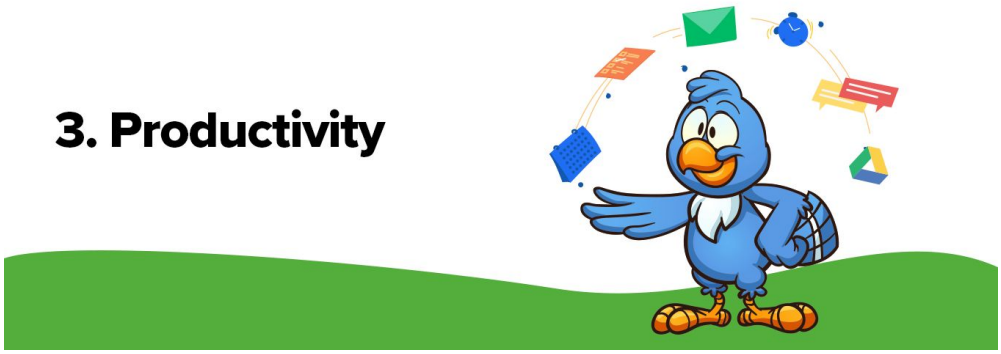
12. Evernote

Evernote has been around forever and is still one of the premier note-taking apps available. Save web pages, bookmark articles, and clip PDFs to the app, or use a pre-made template to build a business plan, a to-do list, or a full-blown research report.

Plans
Basic: Free
Premium: $8 per month
Business: $15 per user/mo.

Productivity software and tools for small businesses

3. Productivity



Workspace Organization

Organizing your digital workspace for optimal focus and productivity and less context switching has become the new standard for employees who moderate multiple accounts across various applications. Aggregating content and information from these apps in a centralized dashboard is where Google Chrome’s web browser falls short and these workspaces shine.

13. Shift

Shift is the modern workstation for highly productive teams and entrepreneurs who want to get things done more efficiently. Shift lets you manage all of your apps, extensions, social media accounts, and email accounts in one beautiful desktop application. It’s the kind of productivity software that changes everything by keeping everything you're doing right in front of you.

Plans
Basic: Free
Advanced: $99 per year

14. Station

Station is a next-generation dashboard that rules all of your apps. The “smart dock” as it’s dubbed, groups all of your apps, tabs, and open web pages in one place to let you context switch and multitask across different accounts, faster. Like Shift, it also comes with a focus feature that lets you turn off notifications so you can concentrate on getting things done.

Plans
Individual: Free
Teams: TBD (as of Feb. 2020)

Time Management

Time management tools help you keep track of time spent throughout the workday. This helps teams optimize effort and productivity with a deeper understanding of how profitable certain projects truly are. After all, time is money when it comes to small business growth.

15. TimeDoctor

TimeDoctor is the productivity cure-all for time wasted. TimeDoctor not only tracks the total amount of time spent on your work, but it also provides an analytical breakdown of how much time is spent on each project, client, or task. Time Doctor is accurate to the second, so you can easily bill clients or pay employees based on tracked time.

Plans
Basic: 14-day trial, then $10 per user/mo.

16. RescueTime

According to ResueTime, only 10% of people say they feel “in control” of how they spend their workday. But focusing for a long period of time on a single task or project can have a massive competitive advantage. RescueTime helps you identify how you spend your time, what you spend it on, and when you’re most likely to perform your best work.

Plans
Basic: Free
Premium: 14-day trial, then $6 per month

Process Automation

Process automation helps teams execute the recurring processes within a common or customized workflow. Even the most complex cross-functional and repetitive processes—like employee onboarding and scheduling—can be automated with ease and in real-time thanks to process automation software and tools.

17. Zapier

Zapier is a best-in-class process automation software for busy teams. Connect more than 1,500 of your favorite business apps and tools so you can focus on your most important work. Zapier automatically moves necessary information between applications with a central command. Stop wasting time on repetitive tasks—automate them—so you can do more of the work you love.

Plans
Basic: Free
Starter: $20 per month
Pro: $50 per month

18. Automate.io

As the tagline says - "Automate like the Fortune 500", Automate.io is an easy-to-use & affordable solution for integrating cloud apps & services to create simple one-to-one integrations or complex workflows.
Users can now automate sales, marketing, and business processes in minutes and save 40+ hrs/week.
And the most interesting part? It doesn't require any IT help and users can integrate their apps without coding through a drag-and-drop interface.

Plans
Basic: Forever Free Plan
Startup: $49/mo
Growth: $99/mo

Scheduling

Small businesses use shared calendar tools for time-management and scheduling.

19. Calendly

Calendly helps small businesses schedule meetings without the back-and-forth of emails. It works with existing Google, Outlook, Office 365, and iCloud calendars and automates tasks with Salesforce and Zapier. Set buffer times between meetings using seamless timezone detection so everyone's on the same page.

Plans
Basic: Free
Premium: $8 per user/mo.
Pro: $12 per user/mo.

20. Doodle

Businesses book meetings faster with Doodle. Quickly schedule 1:1s with outside parties without guessing or inquiring about availability. A first-come, first-served open block for appointments lets guests see and respond to your changing availability without you having to constantly update them.

Plans
Starter: $4 per month
Pro: $6 per month
Team: $30 per month

Marketing software and tools for small businesses

5. Marketing

CRM Apps

Customer relationship management (CRM) software and tools manage all of your company's touchpoints with existing and potential customers—and so much more. A robust CRM solution can help companies stay connected to goals that drive profitability.

21. HubSpot

Hubspot's CRM software brings marketing, sales, and customer service tools together under one roof with popular features like lead generation, analytics, and automation. It puts everything you need to know into a central hub for stakeholders to access. Run a full-blown inbound marketing campaign and share key insights on revenue, traffic, and prospecting. The basic version is free forever, but you can upgrade for advanced features as you scale.

Plans
Basic: Free, upgrade as needed

22. Zoho

Zoho CRM is another popular CRM solution for small businesses that brings companies and customers together via one integrated platform giving marketing, sales, commerce, and customer service an intuitive lens into every customer. Build pipelines and help sales acquire more leads with marketing automation tools and omnichannel workflows that streamline customer journeys at scale.

Plans
Basic: 15-day trial, then $12 per user/mo.

Social Media Marketing

Social media marketing software is used primarily to monitor, manage, and analyze social interactions and automate post scheduling. Aggregate your social media feeds across multiple accounts and stream them via a single dashboard on a range of devices.

23. Buffer

Buffer lets you build your social following and grow your brand by planning, scheduling, and publishing social media content that drives engagement across all the popular social media sites like Facebook, Twitter, LinkedIn, Pinterest, and Instagram.

Plans
Pro: 7-day trial, then $15 per month
Premium: 14-day trial, then $65 per month
Business: 14-day trial, then $99 per month

24. Hootsuite

Hootsuite is a leading all-in-one social media management tool that helps you bolster your social presence. It drives deeper engagement more with customers by automatically scheduling and sending round-the-clock social media posts, comments, and replies.

Plans
Pro: 30-day trial, then $29 per month
Team: 30-day trial, then $129 per month

Email Marketing

Email marketing tools are used to automate and schedule promotional campaigns mainly for products and services. Marketing teams also use these tools to maintain relationships with customers and clients. Email marketing supports a wide range of digital marketing initiatives and is a way to supplement social media marketing and content marketing campaigns.

25. Mailchimp

According to Mailchimp, email marketing averages $52 ROI for every dollar spent. Its industry-leading email marketing tool is part of an all-in-one platform designed to help grow your business faster and increase revenue. Mailchimp is fully customizable and integrates seamlessly with many of the marketing tools on this list.

Plans
Basic: Free
Essentials: $10 per month
Standard: $15 per month

26. ConvertKit

Send emails that pop with ConvertKit's fully customizable templates and embeddable forms lets you collect email addresses directly from your website and turn your readers into subscribers. Tag subscribers based on their interests, activity, and more to help you segment your audiences and send the right message to them at the right time.

Plans
0-1k subscribers: $29 per month
1-3k subscribers: $49 per month
3-5k subscribers: $79 per month

Design Tools

From logos to websites to blog posts to email templates and social media pages—design can distinguish your brand from the competition. Whether you have a single graphic designer on your team or a full creative staff, modern digital design tools allow for varying levels of expertise and functionality.

27. Adobe Creative Cloud

Adobe Creative Cloud is an industry-leading digital design suite with a collection of desktop and mobile apps and services for photography, design, video, web, UX and more. Many professional designers view Adobe as the standard for digital design software.

Plans
Individuals: Starts at $10 per month
Business: Starts at $34 per month

Students & Teachers: $20 per month
Schools & Universities: $15 per month

28. Canva

Canva is the design platform for DIY creatives. Beginner level designers and marketers can utilize stunning, premade templates that make it easy to turn content ideas into professional designs using Canva's drag and drop features. Whether you need a photo collage or a social media mockup, Canva makes it possible for anyone to create amazing designs.

Plans
Basic: Free
Pro: 30-day trial then $10 per month
Enterprise: 30-day trial then $30 per month

Website Builder

A website builder is an all-in-one tool that builds websites without the need for manual coding. A good website builder includes some type of drag-and-drop functionality which allows you to build web pages and structure featured layouts easily. Many website builders incorporate a user-friendly interface that integrates with third-party tools and plugins that dramatically optimize the performance and enhance the functionality of your website.

29. WordPress

According to WordPress, 35% of all websites on the internet use its platform. Choose from more than 54,000 plugin tools—from online stores, image galleries, search and analytics tools, payment platforms, and more—that help showcase your products, services, content and more.

Plans
Basic: Free
Pro: 30-day trial then $10 per month
Enterprise: 30-day trial then $30 per month

30. Wix

Wix is a website builder that gives you the freedom to create, design, manage and develop your web presence the way you want. Whether you're promoting your business, showcasing your work, opening your store or starting a blog—you can do it all with the Wix website builder.

Plans
Personal: $13 per month
Unlimited: $17 per month
Pro: $22 per month
VIP: $39 per month

Website Host

Web hosting software and tools (or website hosting providers) enable businesses to host custom websites or web pages and store their data securely on a protected server network. Most hosting companies will also let you register a custom domain name.

31. GoDaddy

GoDaddy offers more than just a platform to build your website, it offers everything you need to create and run an effective, memorable online business. GoDaddy offers a wide range of affordable hosting plans that include powerful online marketing tools with personalized support.

Plans
Web Hosting: Starts at $6 per month
Wordpress Hosting: $7 per month
Business: Starting at $20 per month

32. Siteground

More than 2 million registered domains use Siteground to host websites. For those businesses that don't know where to start, Siteground offers a full web hosting solution with premium features and the additional support you need to launch your site and keep the engine powered on the back end. Siteground is also widely known for its automated WordPress migration.

Plans
Startup: Starts at $4 per month
GrowBig: $6 per month
GoGeek: Starting at $12 per month

Accounting software and tools for small businesses

Bookkeeping

Track your income and expenses. Manual bookkeeping creates a bottleneck at the end of the fiscal year whereas bookkeeping software allows you to create and maintain financial records throughout the year. This helps you monitor your financial records year-round which in turn helps you forecast and avoid critical errors and future problems.

33. Intuit QuickBooks

QuickBooks has been the holy grail of accounting software for some time and we don’t think that’s changed. Developed by trusted Intuit, QuickBooks is built for small and medium-sized businesses and billed as an all-in-one cloud-based accounting platform for everything from money management, bill pay, and payroll functions..

Plans
Simple Start: $12 per month
Essentials: $20 per month
Plus: $35 per month
Advanced: $75 per month

34. FreshBooks

FreshBooks is an all-in-one cloud accounting software for entrepreneurs and small business teams. It completely automates administrative accounting tasks like tracking expenses, invoicing, and vendor relationship management. Its award-winning customer service is always free and supported by real humans, which for young businesses, is a saving grace.

Plans
Lite: $15 per month
Plus: $25 per month
Premium: $50 per month

Invoicing

35. Xero

Millions of customers use Xero as their go-to accounting software. Its approach to accessibility provides ease of access for business owners and it’s built to scale. But outside of QuickBooks, finding the right kind of accounting software that doesn’t put Mac users at a disadvantage has always been a chore. Xero's cloud-based accounting software (available for both PC and Mac) is a full-suite solution that doesn't compromise functionality on a Mac or an iPhone.

Plans
Early: $9 per month
Growing: $30 per month
Established: $60 per month

36. Wave

Wave is award-winning accounting software designed for entrepreneurs and the majority of its tools are absolutely free—invoicing, payments, payroll, receipts, and more. However, collecting payments via credit card or running payroll comes with a price tag. Wave’s best feature is the ability to fully brand, customize, and personalize invoices with advanced features like recurring billing and automatic payments.

Plans
Basic: Free

Payments

Good payments software is the first and last line of defense when it comes to processing the money going in and going out of your business. Professional payments tools make it extremely easy to issue and collect all forms of payments and manage deductions.

37. PayPal

PayPal for business lets you accept all major forms of payment. Start accepting credit cards and PayPal payments or send invoices online and take payments from your mobile devices. Simply add the PayPal button to your website and give your customers a fast, safer way to pay.

Plans
Standard: $0 per month; 2.9% + $0.30 per transaction
Pro: $35 per month; 2.9% + $0.30 per transaction

38. Stripe

Stripe helps power millions of small businesses in more than 100 countries and across nearly every industry. Start collecting payments via card, ACH, or other popular payment methods instantly. Stripe provides billing software for everything from per-seat pricing to metered billing out of the box. It also gives you the ability to set custom pricing, automate the collection process, and sync billing and payment data with your other accounting software and tools.

Plans
Payments: $0 per month; 2.9% + $0.30 per transaction

Tax Filing

As a small business owner, doing your taxes can be intimidating, but modern tax software can maximize your deductions and help alleviate your frustrations.

39. TurboTax

TurboTax saves you time by transferring last year's information into your TurboTax return. It’ll automatically import your QuickBooks income and expense accounts and classify them for you, as well as walk you through all

your deductible business expenses—from vehicle and supplies to advertising and travel.

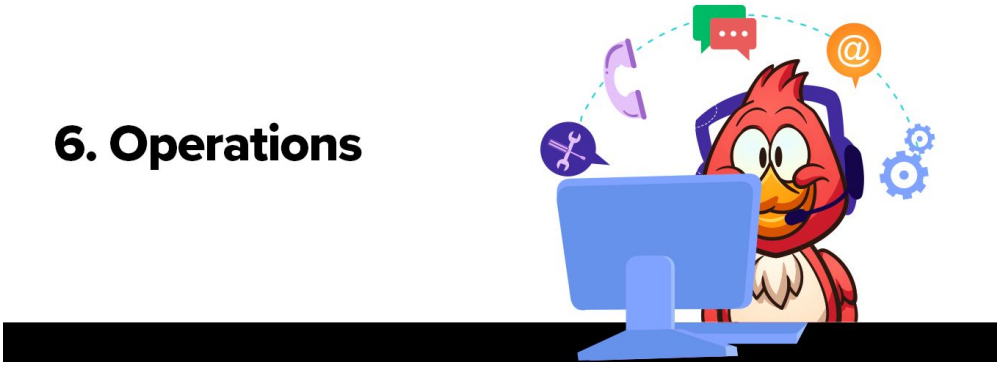
Plans
Federal: $160
State: $50 per state

40. H&R Block

With over 60 years of tax preparation experience, H&R Block is dedicated to serving small business owners with industry-leading software, services, and in-person expert guidance to manage your business' tax needs.

Plans
Federal: $80
State: $37 per state

Operations software and tools for small businesses



Customer Service

Customer support software is a key business tool that allows you to manage customer service requests and track customer engagement using real-time reporting and response times. Most modern customer support software

platforms incorporate a ticket system or a chatbot that utilizes process automation workflows to streamline communication and problem-solving.

41. Zendesk

Zendesk is actually CRM software for support, sales, and customer engagement that's designed for small businesses to create better customer relationships—basically a CRM for customer support. You get an all-in-one help desk solution that generates insightful data on engagement that keeps customers happy and conversations flowing.

Plans
Essential: $5 per user/mo.
Team: $19 per user/mo.
Professional: $49 per user/mo.

42. Help Scout

Help Scout is an all-in-one platform customer support tool designed for small businesses to convert and support your customers. Help Scout offers multi-channel support with email and chat, and additional self-service tools that compile customer data and activity to ensure a great customer lifecycle experience.

Plans
Standard: $20 per user/mo.
Plus: $35 per user/mo.

Contract Management

Legal documents like contracts and formal business filings require authorized signatures. Small businesses can think of contract management software as a digital filing cabinet for all the important documents that contain highly sensitive information.

43. DocuSign

Whether you're approving a purchase, closing a sale, or signing an agreement, DocuSign enables anyone to electronically sign agreements from anywhere. Choose from more than a dozen applications and more than 350 different integrations, covering the entire agreement process—from preparing to signing, acting on, managing agreements, and more.

Plans
Personal: $10 per user/mo.
Standard: $25 per user/mo.
Business Pro: $40 per user/mo.

44. HelloSign

HelloSign makes it easy for small businesses to sign documents or request signatures from up to 20 different people in any order, or all at once. When the document is completed, everyone gets a copy delivered to their inbox. Check your document's progress with status notifications that keep you in the loop throughout the entire process.

Plans
Standard: $13 per user/mo.
Enterprise: $23 per user/mo.

Performance Management

For many small businesses, performance management tools help drive business decisions related to everything from mental health to career development to compensation. Performance reviews set clear expectations and guide employees down the right path by providing periodic feedback relating to the individual, team, and company-wide goals.

45. BambooHR

BambooHR's performance management software collects and organizes all kinds of information throughout the employee lifecycle—hiring, onboarding, evaluation, and more—and gives you the insights you need to support your most important asset: people. Its approach to performance management incorporates the latest tools for measuring engagement that helps you champion culture and drive organizational growth.

Plans
Essentials: $6 per employee/mo.

Advanced: $8 per employee/mo.

46. 15Five

15Five is performance management software that brings the best out of your employees. Its holistic platform lets managers focus on individual and team growth and performance with weekly check-ins, progress updates, and real-time private and private feedback.

Plans
Basic: $7 per user/mo.
Plus: $14 per user/mo.

Recruitment

Recruiting is a human resources and operations management tactic that handles the process of posting jobs and acquiring talent. Recruitment software streamlines the entire candidate search and hiring process—from the job post to the job interview.

47. LinkedIn Recruiter

LinkedIn's recruiter tools help you source the right candidates faster by searching beyond your personal connections with more than 500 million LinkedIn members. Its 20-plus simple-to-use filters and smart recommendations lets you create a search based on ideal candidates you may know and contact them directly on LinkedIn using customized templates. Build, track and manage your workflow with folders, reminders, and to-do lists.

Plans
LinkedIn Lite: $100 per month

48. AngelList

AngelList is more than just an angel investment platform, it's a powerful recruiting tool for startups and small businesses—and a goldmine for top

talent. From seed-stage to post-IPO, 36,000+ of the world’s top startups have built their teams using AngelList.

Plans
Basic: Free
Source: $200 per month
A-List: 20% per hire

Learning and Development

Providing on-the-job training and investing in employee development and growth is part of a winning operational approach that cultivates core culture and grooms budding talent.

49. LinkedIn Learning

LinkedIn is the world's largest professional network with nearly 660+ million users worldwide. Formerly Lynda.com, LinkedIn Learning lets you pick and choose the courses you want—from business, engineering, creative, and more—and as many as you want for one affordable monthly cost. Choose from a huge depository of professional courses online and complete them at your own pace.

Plans
Monthly: 30-day trial then $30 per month
Annually: 30-day trial then $20 per month

50. General Assembly

General Assembly is a leading source for training, staffing, and career transitioning. It specializes in today’s most in-demand skills from web development, data, design, digital marketing, business, and more. Businesses can leverage its 40,000-plus professional alumni to provide mentorship, help employees fill skills gaps, and foster a culture of lifelong learning.

Plans
Varies by course

Whether you are a small business owner or heading multiple businesses, there would always be a number of activities going on every time. It could be a challenge to handle too many things at once and not let work become chaotic. This is why it makes sense for businesses to start using a business management software to stay on top of things.

These days more and more organizations or companies are investing in business management software to get things done, predict risks, and improve overall efficiency. Thus, it won't be wrong to say that business management tools have come a long way and are constantly making things better for anyone involved in some sort of business.

Before we move further, let's take a moment to define a business software and discuss its types briefly.

List of top 17 business management software

Let's take a look at 17 best business management software that you should start using as early as possible:

1. ProofHub

ProofHub is a powerful business management software and platform that combines all the features you might need to take care of your business. You can streamline your processes, store and share files, share feedback under one roof with ProofHub. Its mobile app can be used by both Android and iOS users on the go.

Top features:

- Effective project and task management
- Gantt charts to keep your projects on track
- Dynamic reports to get clear insights
- Time tracking to track time spent on tasks

Start managing your teams and projects efficiently with ProofHub!

2. Todo.vu

Whether you are a consultant, freelancer, or small agency needing to track work across multiple projects, Todo.vu could be the right fit for your needs. It is a simple company management software that focuses on getting things done. It brings all your customer management and project management in one place with a beautiful and neat interface.

Top features:

- Intuitive user interface
- Focused communication and real-time updates
- Built-in time tracking and billing
- Sync tasks with any calendar

3. StudioCloud

StudioCloud has made a name for itself as a reliable business management platform and company management system in much less time. It is a one-stop solution for your business needs that contains all the features you need to manage your business anytime, anywhere. Go check this business tool to organize and simplify your life.

Top features:

- Manage clients, partners, and vendors at one place
- Create and send professional invoices
- Send automated, personalized, text and email reminders
- Have clients review and sign contracts online
- Easily customize the look and feel of your software

4. Timely

Knowing how your business spends time is elementary, whether you bill for it or not. Timely streamlines the whole time tracking process by recording

everything your team works on automatically. It dramatically reduces time management overhead, while improving reporting and invoicing accuracy.

Top features:

- Automatic time tracking
- Real-time project dashboards
- Sophisticated, client-friendly reporting
- Hourly rates, capacity and overtime

5. Zoho One

Zoho One is a wholesome business management software and company management system that has everything you need to run your business on the operating system for your business with impressive 40 business apps. You just need to connect multiple apps so that different teams can work together productively.

Top features:

- Manage almost every aspect of your business in one system
- Fosters collaboration with online document storage and sharing
- Automate personalized business workflows

6. Scoro

Scoro is an all-in-one business management software designed to bring your teams, projects, sales, and reports together at a centralized place. With Scoro you can manage work more efficiently and be organized in every aspect of your business.

Top features:

- Plan and track work with unlimited projects

- Manage quotes, contacts, and invoices seamlessly
- Track time and bill for completed work accurately
- Manage your entire business within a single solution

7. iBE.net

As a business management software/ company management system, iBE.net is an appropriate choice for mid-sized companies as it offers expense tracking, invoice reports, CRM support along with an easy integration of project details. It is extensively used in consulting, marketing, management, and other technical industries. It is like your entire business within your palm of hands.

Top features:

- Customize your own dashboards
- Use pre-delivered reports
- Generate invoices in seconds
- Visualize, analyze, and organize your data with valuable insights

8. Odoo

Odoo is an all-in-one business management software that offers a range of business applications which forms a complete suite of enterprise management applications. It covers CRM, eCommerce, accounting, inventory, sales, and project management. Odoo apps are perfectly integrated with each other, allowing you to fully automate your business processes.

Top features:

- Unique framework with strong technical foundations
- Take a quick look at your business with dashboards

- Real-time communication makes way for better collaboration

9. Netsuite

Netsuite is a unified business management suite being used by more than 40,000 large, mid-sized, and small fast-growing businesses. It provides various tools for ERP, Financials, CRM, HR, eCommerce. It offers comprehensive functionality with industry-specific support for a broad range of industries means NetSuite works the way your business works.

Top features:

- Cloud-based, mobile-enabled, and social
- Easily accessible reports and key performance indicators
- Highly flexible and customizable
- Effective resource management, project accounting, timesheet and expense management

10. Timecamp

Timecamp is a one-solution-fits-all business management solution that comes with a time tracker with computer activities, productivity monitoring, attendance tracking, integrations and more. The software tracks time automatically so you don’t have to worry about spending hours on figuring out how to do it. TimeCamp offers you an intuitive interface to get your team on board effortlessly.

Top features:

- Create and send invoices based on time tracked per project and customer
- Seamless integrations with project management, accounting, help desk software and more
- Simple and intuitive interface

- assign the time entries to the right project, monitor employees' internet usage and generate detailed reports
- Desktop and mobile app available for many platforms and devices

11. Bitrix24

If you are looking for a software that offers a complete suite of management, collaboration, and communication tools, then Bitrix24 could be the ideal choice for your business. It is a complete business management software that takes care of your tasks and projects to document management along with real-time **communication tools** from video conferencing to group chat.

Top features:

- An internal social network lets you collaborate easier, faster and more efficiently
- Get instant feedback, share ideas, create workgroups and engage your employees
- online multi-user editing and custom document approval workflows
- Sell more with Bitrix24's CRM and sales team management
- It works on your iPhone, iPad or Android too

12. Apptivo

Apptivo delivers a wide array of functionalities in customer relationship management (CRM). It also helps your business to grow with project management, invoicing, and timesheet capabilities. If your business process has some specific needs, it can be easily customized.

Top features:

- Track the complete sales process from anywhere with the online CRM software
- Collaborate on tasks, manage timesheets, and log expense reports

- Powerful ticketing system to deliver stellar customer support
- Billing system to send and receive online payments from anywhere
- Supply chain management with vendor tracking, purchasing, and inventory

13. HoneyBook

HoneyBook is an all-in-one business management platform and company management system. From first contact to booking your ideal client, HoneyBook makes it easy for you to capture leads, manage projects, automate workflows, send contracts and invoices, and get paid.

Top features:

- Mobile app so you can manage your business on the go
- Proposals and invoices optimized to get you booked
- Contracts your clients can sign in seconds
- Easy and intuitive workflows
- Design forward client experience

14. Atlassian JIRA

JIRA is a workflow mapping and project planning software that is designed to help software development teams of all sizes and industries. Kanban boards, burnout charts, project reporting tools, etc are some of the popular capabilities of this tool that support teams at various stages of the development lifecycle. Also, it integrates with various developer tools and is available as a cloud-based or on-premise solution.

Top features:

- Roadmaps that are connected to real work
- Visualizing work in progress

- Bugs and defect management
- Polished user experience
- Customizable dashboards and wallboards

15. Trello

Trello is a web-based project management application that is designed to fit every unique need and work styles. From sales and marketing to HR and software development, Trello helps teams to customize its functionality to meet their specific project management needs. And with more than 100+ integrations (including tools like Google Drive, Slack, Jira and more), Trello makes it easier for teams to get their ideas to action in seconds.

Top features:

- Easy organization with tags, labels, and categories
- Drag and drop functionality
- Mobile functionality to access boards on the go
- Quick overview on front and back of cards
- Texts and visuals fit any screen size

16. Favro

Favro is an all-in-one project planning and collaboration software that is designed to help teams stay on the same page. The features and functionalities of this software solution scale across any business or team. So, whether you’re a team of developers, marketers, or executives, Favro works for all. It improves flexibility and visibility across projects by bringing teams in one place.

Top features:

- Multiple view boards
- Department collections

- Time reporting
- Time sheets
- Estimation fields

17. Connecteam

Connecteam is a leading business management software solution, designed for deskless teams and Enterprise companies. Taking care of your business operations has never been easier with robust features that can be managed while on the go and at any time. From time tracking to job scheduling, automated checklists and forms, one-on-one or group chat, surveys, digital training and onboarding, efficient task management, and so much more is available on a sleek and easy to use interface.

Top features:

- GPS empowered time tracking
- Efficient timesheet management and payroll processing
- Real-time and detailed reports
- Streamlined communication and better engagement
- Simple and intuitive job scheduling – from planning to distribution
- Better transparency and accountability with on the go task management

What is a business management software?

A business management software, by definition is *an application or set of programs that help businesses support, improve, and automate their processes*. Such software assist in eliminating errors, completing business tasks, reporting activities and increases overall efficiency and effectiveness.

All in all, a business management tool or company management system is designed in such a way that it meets the requirements of business processes in the most effective manner.

Types of commonly used business management software/ company management system

Deciding a project management software for your business or company isn't always an easy task as there are different types of business software used for different purposes. Below are some commonly used software in businesses:

- Business invoicing programs
- Asset management software
- Customer relationship management (CRM) software
- Database software
- Word processing programs

How to choose the right company or business management software and platform

There are so many factors that go into consideration while choosing a management software for your business. It depends on factors such as the size, needs, tasks, and processes that need to be automated in a business. Besides, make sure your business management software and company management system has the following features:

- Project and task management
- Time tracking capabilities
- File storage and document sharing
- Invoice and budget management
- Resource management

Marketing Tools for Semiconductor Startups

Business & Project Name Generators

Many small business owners have great ideas for products and services, but struggle to come up with a compelling name for their business. Instead of wasting time being frustrated then you should consider using one of these **online marketing tools for your small business**.

These naming services offer different types of benefits, but you will thank yourself for using one (or more) of these generators **instead of wasting valuable time** trying to think of names for your small business on your own.

NameStation

Coming up with a name for your startup or small business can be difficult, time- consuming, and frustrating. Instead of wasting hours trying to find a name that is available and has a corresponding domain name, you can use this community to find the perfect name in no time.

There is an option to host a competition for about $35, and this is an excellent option if you have a few dollars, but you can also look at past contests to find names that were not chosen by the hosts.

The Name App: Can’t think of the best name for your app? No problem- just use this free and easy to use tool to choose the best name for your next big idea.

Naminum

Start with a base idea for your business name, and Naminum will do the rest for you. Once you put in the starting point of your business name this generator will return a list of potential names that you could choose from.

However, remember these names are not verified to have domains so you could find a few great names but they are not available.

Short Domain Search: One of the best ways to keep your branding consistent at all levels of your online business is to have a branded short URL. This tool will help you find a shortened URL that you can use for anything from Twitter posts to putting on your printed business cards.

Wordoid

If you want to generate a business name based on fake or shortened existing words then this tool is for you. Just be careful because this tool often removes vowels, so it could be difficult to distinguish your business name if you choose one of the options listed in the tool.

Hipster Business Name

While it is a basic name generator that is based on refreshing a set list of names, this name generator could be the perfect solution if you have a mental block in choosing a business name. Probably not the answer you will need for your startup or small business, but who knows- it could help you on your journey!

Impossibility: One of the best domain name generators available. Choose from a list of options and work from a base keyword that you want to use in your domain.

This tool makes finding a great domain name smooth and efficient, without having to juggle between multiple devices or websites.

Lean Domain Search

Enter a specific word that you want to include in your domain name and hit ‘Search.’ This domain name generator was made for entrepreneurs who wish a domain name without all the bells and whistles that can cost them time or energy.

Domainr

Another domain name generator that delivers domain name ideas based on keywords. The only difference with this option is that you can find shortened domain names in a range of possibilities and TLDs.

This means you know which domains are available and can even see shortened domain names associated with your primary domain name!

Website Builders

Whether your small business is just getting started or you have been in business for a while, **you need a strong online presence**. Often small business owners lack the knowledge or time to develop a website that will help them stand out from their competition.

This is why your small business can use these **marketing tools** to design and launch a fantastic site in almost no time for free! You can use these tools to focus on writing amazing content for your website instead of worrying about coding or other aspects of building a great online presence.

HTML5 UP

Responsive HTML5 and CSS3 site templates. Great option if you want a simple HTML 5 website- free templates do quick work for setting up your business website.

If you are not web savvy or have the time to learn how to set up an HTML5 site from scratch, then you should consider using a service like WordPress.com or another option.

Bootswatch

Free themes for Bootstrap. Whether you are building an app or interactive Bootstrap site, Simply download a CSS file and replace the one Bootstrap. No messing around with hex values.

Templated

A collection of 866 free CSS & HTML5 site templates. Built by a team of dedicated designers and coders, all of these beautiful designed CSS & HTML5 templates are released under the Creative Commons, so your startup or business is free to use them as you need.

WordPress

Create your new website for free. WordPress is the most used CMS for all types of sites, and it is an excellent choice no matter what industry your startup or business is in.

While it is easy to use and quick to get set up, you might need a professional to help with some of the more excellent details.

Strikingly

Free, unlimited mobile-optimized websites for striking domains. This is also a great tool to conduct A/B tests on landing pages quickly.

While it is not a go-to solution for landing page testing, Strikingly can be an excellent choice for testing ideas to improve conversions.

Layers

If you choose to go with WordPress for your website, Layers could be the builder of your dreams. This free WordPress builder will allow your business to build a great looking website in no time.

Bootstrap Zero

A great collection of free and premium themes for your Bootstrap needs. This site contains everything from full ideas to mockups and icon images.

Branding & Logo Generators

Your small business exists to deliver amazing products and services to your customers and **help them reach their goals**. However, if your customers can’t identify you online with a distinctive brand and/or logo, then your small business will fade away.

These **small business marketing tools** are easy to use and free options to help you develop a logo and branding if you are in a hurry. While you should not rely on these tools for a long-term logo, you can use these **free online marketing tools** to develop content to get your business started in the right direction.

Logogenie

This amazing logo generator is one of the easiest to use and intuitive tool on the market. While it is not free, at only $19.95 this tool can help you find the perfect logo at a fraction of the cost that you could spend with other solutions.

DesignEvo

DesignEvo is a free online logo maker with 5000+ templates that anyone can use to bring to life a compelling, unique logo in minutes.

Logaster

There are several free logo creators out there, and Logaster is one of the best ones on the market. Offering a fast and straightforward process to create great looking logos, just have to type in the name of your business and the type of industry you serve.

Hipster Logo Generator

This logo generator moves to a different beat, and you can generate a logo in no time that will stand out then you should check out Hipster Logo Generator.

Squarespace Free Logo

While not the easiest to use, this logo generator allows you to preview how your logo could look on a variety of mediums like shirts and coffee mugs.

Invoice Creation Solutions

You work hard to run your small business, but you should not have to work hard to collect money from your customers. Depending on the needs of your business, you can use these **free marketing tools** to generate free invoices.

The small business invoicing tools are a great addition to any **small business marketing toolkit** because they are a quick and easy way to create professional invoices to send your clients.

Invoicely

If your startup or small business is in a pinch to generate a professional looking invoice, then you can’t go wrong with Invoice to me. While not the most feature-rich option available, this invoice generator is free and will get the job done.

Free Invoice Generator

Your alternative invoice generator uses a simple and straightforward interface so you can create business invoices in no time flat.

Slimvoice

Straightforward invoice processing tool that your business can use on an ongoing basis. The paid version allows you to track invoices and provides a holistic SaaS model service for your business.

Wave

Wave is an excellent alternative to more extensive invoicing systems like Freshbooks. While the free version is a bit limiting, the overall service should be able to meet the needs of your business or startup.

Invoice.to

No bells or whistles here- just a simple, easy to use interface to generate quick invoices. If you only need to make an invoice to send to a client, then this could be the option you are looking for.

Just be careful- not many options means no saving or tracking like is available in other tools.

Legal Documents & Agreements

One of the most critical aspects of a small business that is often overlooked are legal documentation and agreements. Many small business owners are excited to engage with their customers but **forget about the legal side of their endeavors**.

Neglecting legal documents and contracts can cause serious issues for your business, and this is why you should check out these **small business marketing tools** to help you ensure your legal standing before committing to anything in your business.

Kiss

Your startup or small business might not have the budget for an attorney to draft simple notes or other documents for you. The KISS docs are short and sweet “open source” documents prepared after multiple discussions with some Silicon Valley law firms and early-stage investors.

Democracy

No matter the type of agreement you are looking for, Democracy likely has you covered. Everything from parking agreements to specific contracts with designers, you can find what you need in this easy to navigate community.

Just be careful- there are trolls in the forums and always make sure the agreements work for your situation.

Shake

Sending legal documents can be a pain, but Shake makes the process more comfortable and less complicated than ever before.

Idea Management Programs

Are you struggling to come up or validate new ideas for upcoming products or services? These **online marketing tools for small business** can help you generate and validate your ideas quickly so you will waste less time and resources in the process.

Xtensio

Thousands of entrepreneurs reduce design-related costs, improve the quality of their business collateral and save time with Xtensio. You can create anything with Xtensio: Reports, pitches, proposals, landing pages…whatever your business needs.

Experiment Board

Many startups fail because they fail to identify the core problems of their audience and build their solutions around their market. Javelin offers a free option to find your customers’ issues, create a landing page, and test your assumptions without investing large amounts of money or resources.

This is a great tool that all startups and small business should use before launching new products or services.

Germ.io: While there are many collaboration tools on the market, Germ.io is an excellent choice if your startup or small business relies on a core team of developers and strategists.

You can use this tool to keep all your ideas in one place and track how the team is contributing to your goal from a holistic perspective.

Skitch

This annotation tool used to be part of the broader Evernote ecosystem, but since it's creation Skitch has become a stand-alone tool. Taking screenshots and making quick notes has never been easier.

This is a great tool to use when sharing ideas about your startup or business online resources.

Business Blogging Solutions

If you want your small business to grow, then you need to check out these **free blogging tools for your small business**. Business blogging can have a significant impact on your online marketing strategy, and developing great content has never been easier than with these **small business marketing tools**.

Some of the free marketing tools will help you publish your content quickly and efficiently, while others offer platforms to share your ideas and build trust with your audience. This means that you can produce engaging content for your blog that will attract more readers and establish yourself as a thought-leader.

Hemingway

This is one of my go-to apps when I am writing blog posts for myself or my clients. Hemingway App helps writers at all levels rid their writing of run-on sentences, needless adverbs, passive voice, and opaque words.

Grammarly

If you use only one app on a daily basis, then be sure to use Grammarly. Not only will this free tool save you a lot of time editing your online content, but it will also help protect you from the embarrassment of simple typos and grammatical mistakes.

Be sure to install this app and use it whenever you are writing an email or drafting an invoice to a client!

Medium

If you are just starting up your business then you might want to consider using Medium to track your initial progress. This is a community-focused content generation platform that can help you connect with others in your field.

Just be sure to look at writing for your website so you can capture SEO value as your business grows, but Medium could provide the boost you need in the early stages.

ZenPen

Do you get distracted quickly with all the options Microsoft Word or Google Docs have in them when you write online? ZenPen is the most simple and straightforward writing platform that you will find online.

Start up this program, and you will have nothing to look at except for the words you are writing!

Editorial Calendar

If you want your online marketing to take off quickly then you and your business team will need an editorial calendar.

Sure, you could keep an Excel file with all the content plans in it, but you can also use a simple and free WordPress plugin like Editorial Calendar to do all the heavy lifting for you.

WP Hide Post

Creating and maintaining a business blog on WordPress is simple, but it can be difficult to have full control over how your content displays if you don’t know how to code.

This free WordPress plugin makes it easy to alter the default layout of your posts on your WordPress site without ever having to write a single line of

code.

Social Locker

Do you have a fantastic piece of content that you know your customers will want to have? You can use a free WordPress plugin like Social Locker to entice your readers to share your content with their friends to gain access to your most valuable content.

Just take into consideration that social shares are not as valuable as your customer's email address for your business and that the content you have behind this paywall needs to be high- quality if you want to retain your readership.

Egg Timer

This is an excellent tool if you want to improve productivity. You can set countdown times right from your web browser, and keep yourself accountable to focus on a single task for a fixed amount of time.

CoSchedule

Don't hit publish until you know your headline is fantastic because the success of your content often relies on the quality of your headlines.

Use this free tool to analyze the headline of your content, and receive an easy to understand overview of your content headline. Plus, you will learn how you can improve your content headline to increase engagement.

A5.gg

Use this minimalist and easy to use typing tool to record notes or write entire blog posts.

Free Summarizer

Do you have several long documents that you need to read, but don't have the time to read everything? This free summarizing tool will help pull the most critical points of a document and display in an easy to understand format.

Just be sure you test this before using with any critical information- the results can vary, and you don't want to miss a great opportunity because Free Summarizer didn't capture everything that you needed to know!

Trending Content Discovery

The success of your **small business marketing strategy** depends on producing relevant content that is valuable to your audience. One of the hardest parts of marketing your business is to understand what your customers want, and one way to accomplish this is by looking at trending topics.

This free tool helps identify various topics in the market and determine the popularity of content and topics based on monthly searches.

Buzzsumo

This is one of the best platforms to analyze content and ideas that are shared in general or do some spying on your competitors.

Use this tool before writing a blog post or engaging with your brand online to be sure you are spending your time and resources on the topics that matter most to your audience.

Hubspot Blog Topic Generator

If you are struggling to come up with great blog post ideas and titles then this tool is for you.

The results are pretty necessary, but if you want to get some ideas to get started then you can’t do much better than this tool!

Content Gems

Content Gems is one of the best curation tools on the market to find the most popular stories for a set of keywords. Whether you are looking for topics to write about or want a comfortable place to discover content for your social media accounts, you can’t go wrong with Content Gems.

The free dashboard allows for one panel with up to five keywords, so you are sure to find the content and ideas you need.

Research & Website Analyzers

SEO can be an overwhelming aspect for many small business owners, but you can help remove much of the guesswork, so you have accurate data. These **free online marketing tools for small business** will offer you insight and data that you can use to develop compelling content to drive qualified leads to your website.

Writing content that your audience wants to read while also marketing search engines isn't easy. This is why you should use the best tool on the market to help your business grow.

Many of these online marketing tools offer different benefits that your small business can use, so be sure to test out each one depending on your needs.

Ahrefs

Ahrefs.com is a well-known toolset for backlinks and SEO analysis. Ahrefs can easily replace several tools and has already become essential for any SEO since it gives you new ideas for link-building and content analysis; social stats and ratings; export of any data for further analysis on your own; various charts and graphs for visual representation and much more...

Socialinsider

Socialinsider is a social media analytics tool which shows you a full view of a competitor's digital strategy for Facebook, Instagram & Twitter. You can use this tool to compare side by side social profiles and create benchmarks for your industry. Plus, Socialinsider lets you create white-label reports with aggregate data and statistics about your social media performance.

Wondersearch

Wondersearch is a powerful keyword research tool that scrapes Google based on specific keywords. Unlike other keyword research tools, Wondersearch focuses attention for people also search for, people also ask, and by the end of today, the brand new, topics they write about (for authors and publications). The tool also displays metrics like fresh average monthly search volume, average CPC, and PPC difficulty.

Open Site Explorer

Developed by Moz, Open Site Explorer is an excellent tool for startups and businesses that want to research backlinks and find new opportunities to grow online.

You can search your site or a competitor site to understand your market in a new light.

SEMrush

Essentially an all-in-one marketing tool, this go-to tool provides startups and small businesses with valuable information about their competition and to find great opportunities in their market.

The free version of SEMrush is capable of handling your needs to find right keywords while also doing some recon on your competition.

QuickSprout

From time to time you should analyze your website to find areas that can be improved to grow your online presence.

Once you put your URL into Quick Sprout, you will be given actionable advice to make changes to your site that can have a significant impact on your online rankings.

WordPress SEO by Yoast

If you are using WordPress to run your website then you should consider using this free WordPress plugin.

Not only does Yoast help you focus on the things that matter in your content to get you ranking in Google, but this plugin also handles the tedious tasks of online marketing like ensuring your meta information is correct. A big time saver and the best SEO WordPress plugin available.

SEO Site Checkup

Whether you are just starting your business or your startup is the few years old, the chances are that your website can be improved.

SEO SiteCheckup provides an overview of how your website is performing on a technical level so you can optimize your site to perform better and rank higher in Google.

Hubspot Marketing Grader

Another free website evaluation tool, Hubspot's online tool gives deep insight into the performance of your website.

Just enter your URL and email address, and you will see an overview of your website's health on everything from Mobile, Security, and general SEO issues. This tool is excellent to use as you grow your website or make changes to ensure the integrity of your site.

SimilarWeb

As you build you're your content strategy you will want to find sites similar to yours. This information can help you develop a great marketing plan, improve your content, or identify competitors to look at their backlink library.

OpenLinkProfiler

Backlinks are one of the best ways to get your business ranking on Google, and you should use every tool you can find to understand the backlink profile of your competition.

Just enter a competitor's domain name into this free tool and find a list of sites linking to your them. You can use this information to reach out to these sites and build relationships to grow your backlink profile!

Keywordtool.io

There are a lot of tools out there to help you build keyword lists for SEO, but few compare to Keyword Tool. Enter in a primary keyword, choose your country and language and let this tool do the rest.

While some of the results are not relevant, you can also use this tool to find negative keywords if you run PPC advertising campaigns.

LSI Graph

Google's algorithm is constantly changing, and many SEO experts agree that LSI keywords are becoming essential to help sites rank. You can use LSI Graph to find associated keywords to your primary keywords.

This improves your keyword footprint so your site will show up for a broader range of words while helping Google and your readers understand your content better.

If you have a website, then you need to be tracking your customers to determine what content is valuable and how you can expand your online presence.

Google Analytics is the most used analytics tool for business owners of all sizes, and if you have a website, then you should have GA installed.

Broken Links

Broken links can have a negative impact on the SEO performance of your site. If your startup has developed an extensive content library, then you should consider checking the health of your on-site links.

This free tool provides a comprehensive overview of active and broken links on your site so you can clean up broken links to improve your online presence.

As you grow your startup you will need to focus on a lot of things like finances and marketing. If the technical side of online marketing is not your strength, then you should use a tool like Google Pagespeed Insights to see if your website is ranking low due to on-page issues.

While this tool is not perfect, it does provide great insight on what you should focus your attention on to improve your site performance.

Pingdom

Another great free tool to help evaluate the speed and performance of your site from a technical perspective. Just enter your URL, and this tool will provide deep insight into the load speed and other functional elements of your site.

This information can help you optimize the code and other on-page features to improve user experience and rank higher in Google.

GTMetrix

Quickly and easily analyze your URL to learn about potential performance issues. The results are laid out in a format that is easy to read and provides actionable tips to improve your site.

This is a great tool to use in conjunction with the other URL analyzer tools because it allows for a different perspective and evaluates additional aspects of your site.

Moz Local

Local SEO is one of the most important aspects of SEO. Whether you have an online business or a brick and mortar store, you need to have a solid Local SEO strategy if you want to reach your target audience.

While this tool won't help you build citations, it can help you determine your current standings and guide you in the best direction to improve your Local SEO rankings.

Shopify E-commerce Report

You can find a wide range of resources here, tailored perfectly for your small business or startup. Use these tools to help design a logo, generate terms and agreements, and even create barcodes.

You will need to look around at all the resources since there are many choices to choose from based on your business needs.

Majestic SEO

If you are building backlinks for your business then you need to be sure that these links are quality before you agree to have them point to your site. This is because spammy backlinks can cause a drop in your online presence and even cause Google to drop your website from their search engine altogether.

Majestic SEO is a great tool to help you find the true value of sites linking back to you and this tool can help save your business from the stress and lost sales of getting a Google Penalty.

Image Optimization Tools

If your small business relies on images to show your products or services, then you likely have lots of images on your site. If you are not careful then your website can become slow and not only will this , a slow site will also drive your customers away.

You can use these **free marketing tools for your small business** to optimize your online images to ensure the speed and usability of your site.

TinyJPG | TinyPNG

The speed of your site can have a significant impact on your online rankings and SEO. Since images can take a long time to load, you can use this free tool to compress images before you upload them to your site.

There is also an option to install a free (and paid option) WordPress plugin that will automatically optimize and compress any image you add to your site. This is an excellent addition to any startup toolkit since it will help your website rank in Google and improve the user experience.

Compressor.io

Compressor.io is a powerful online tool for drastically reducing the dimensions of your pictures and photos while maintaining a high quality with practically no visual difference between the image before and after you upload.

Smush.it

Another great free WordPress plugin that allows you to resize images when you upload media to your site automatically. This plugin can also resize your images automatically for thumbnails, and other common usages for your WordPress theme.

This is one of the go-to tools for startups looking to ensure that their website is as fast as possible.

Dunnnk

Quickly and easily create amazing mockups that include your logo or app in stock images. This is an excellent solution if you need to create assets to help sell your products or build out an information page on your website.

If you are a tech startup creating an app, then you should consider using this free mockup generator today!

Creative Assets & Mockups

Creating customized assets for your small business can take a lot of time, and hiring a designer can be expensive. There are some **high-quality small business marketing tools** that your company can use to leverage a library of pre-made creative assets that are distributed for free by a community of skilled designers.

These **online marketing tools** provide your business with great ways to look professional at a fraction of the cost.

Freebbble

No matter what your startup is looking to build, your marketing efforts can be improved by searching Freebbble for free assets. This is a great location to find a variety of free digital assets to include in your marketing and outreach efforts.

Find items like header images, landing page mockups, and other engaging content to help save your startup time and money!

Dribbble

Dribbble is a great place to find high-quality assets for your startup. Things get even better when you search for “Freebies” in Dribble and here you can find an assortment of high- quality digital assets to meet any need that your startup might have.

You can use these assets to build out unique landing pages, apps, or other projects.

Graphic Burger: This is a great website to find fabulous mockups, PSD files, and other even t- shirt designs. Your startups are sure to find digital assets on this site to meet your needs, no matter your project!

Pixel Buddha

Your startup can find some of a unique assortment of free digital assets at Pixel Buddha. Find everything from Vector images, templates, and other mockups.

Premium Pixels

While Premium Pixels has a great selection of all types of assets, you will find a wide range of icons and other assets for mobile app development. Be sure to check back often because the site is updated with free assets frequently.

Fribbble

This is one of the best sources for patterns and textures to help your startup personalize your online presence. If your startup wants to have a brand that stands out, then this is the place for you.

Freebiesbug

While many other websites host textures and patterns to be by designers, Freebiesburg specializes in digital assets for mobile app developers. You can make your app, and other projects look professional without wasting time and energy.

365 Psd:

There are so many icons, templates, and UI kits on 365 PSD that it is hard to think about what you can’t find on this site. Be sure to check out the Free PSD and Free Vector menus to discover professional assets that are not featured on the homepage.

Dbf: Stock images, typeface, and mockups are a must have for all startups looking to cut their production time in half. DBF is an excellent source to check out if you want to ensure your online presence has a polished look.

UI Space

Where do professional designers go to share their scripts, mockups, and icons for free? You won’t be disappointed if you choose any of the freebies from UI Space.

Freepik

Choose from a wide selection of free PSD files, Vector images and stock photos for any season or occasion. One of the best things about Freepik is the ease of use and variety of choices. This means that your startup can develop a comprehensive marketing strategy.

Tethr

Is your startup developing an app or game for iOS? If so, then Tethr could be the resource you have been waiting for. Not only is Tethr the best design kit for iOS, but it also happens to be free!

Image Editing Software

As your **marketing strategy develops**, your small business will need to use the best marketing tools to help you edit images for your website, social media, and other areas.

These **free online marketing tools for small business** will help you make quick edits to your images while saving money on the expensive photo editing software that your company likely doesn't need.

Piktochart:

As your start continues to grow, your content strategy will likely begin to incorporate infographics and other visuals to engage with your readers on social media. Piktochart is one of the best free infographic design programs on the market.

Get your free account set up and you can start designing beautiful infographics to drive traffic and earn backlinks for your startup.

Pixlr:

If you need to edit an image then Pixlr is the best free image editing program available. While this image editor is not as robust as Adobe Photoshop, you can upload and manipulate images in no time.

Great for startups who don't want to worry about licenses or expensive programs, because Pixlr is entirely web-based.

Canva:

Canva is another free infographic generator, but the real power of Canva is the ability to create stunning images for social media quickly. This tool helps

you create images for the specific dimensions that various social networks require.

This means that your startup can create and publish high content for your social media followers without wasting time and energy!

Easel.ly:

This is one of the most straightforward infographic generator tools on the market, and Easel.ly has an extensive library of templates to choose from. Like other tools, your startup can quickly create stunning infographics that you can share with your audience.

Social Image Resizer Tool:

As your startup begins to generate impressive images to share on social media, you want to make sure that these images are sized correctly. Otherwise, you risk losing the first impression- even if you have great visuals.

This free tool allows you to upload your pictures and then resize them depending on the social network you want to share on. Great for saving time and building a robust online following to grow your startup marketing strategy!

Placeit:

Even if your startup just launched, you need to ensure that your online presence has a strong presence. You can create a great impression by including great looking mockups of people using your product.

Not only is this a great way to build trust with your audience, creating mockup material of people using your app or product can help drive sales once you attract qualified customers to your site!

Recite:

Make your quotes look more inspirational with this free design tool. You can also use this tool to create content for your social media accounts!

Meme Generator:

Memes are not only funny, but they can also be a great way to make a statement about your startup. Instead of struggling with advanced image editors, you can create great memes with this easy to use meme generator.

Pablo: Engage with your social media followers by using this quick and easy image generation tool. Each image that you create will be correctly sized based on the social network of your choice.

Stock Photography

Whether you are using them for your website, blog posts, or other marketing materials, images play a crucial part in the overall **success of your marketing strategy**. Instead of spending lots of money on expensive photos, you can use some of the **best free online marketing tools for small business** owners to find photos that free to use.

Stock Up:

One of the largest and most complete free photos for your website or blog in one place. The images tend to have a traditional approach, and many of the images don’t have filters, so you can adjust as needed.

Pexels:

Pexels is one of my favorite sources to find photos because they have an artistic twist to them. Find thought-provoking images to feature on your blog or website.

All The Free Stock:

Powerful source for free photos, icons, mockups, and videos. One of the best things about this resource is that you can search some photo sites without having to jump around to different sites!

Unsplash:

Find engaging and high-quality photos for free. This means that you can use photos on this site for anything- from developing your website or app to email marketing campaigns and blog posts.

Startup Stock Photos:

If your startup wants to show your unique qualities with images then you can't go wrong with using some photos from Startup Stock Photography. All of the photos on this site feature startup environments.

Jay Mantri:

You can find a wide range of artistic photos on this site, and one of the best things is that you can use the images for anything. This is an excellent source of photos that feature cities, people in action, and unusual perspectives.

Travel Coffee Book:

Beautiful images from various travel photographers. These photos are sure to satisfy your need for exotic or rarely seen locations. These are great for in-post images or other assets to build a message to appeal to your audience.

Designers Pics:

Free photographs for personal and commercial use that don't require attribution are difficult to come by. However, Designers Pics offers high-resolution images that your startup can use without having to worry about attribution!

Death to the Stock Photo:

This stock photo resource is slightly different from other similar services because Death to Stock sends a small set of stock photos to your email each month. There are not as many photos to choose from at this site, but the quality of each photo can't be matched.

Foodie's Feed:

This is a beautiful selection of minimalistic lifestyle images to use on your website or blog.

Mazwai:

Large selection of free Creative Commons videos and video clips to use for your marketing campaigns.

Pixabay:

Free, high-quality images that you can use in your online marketing campaigns like website development and blogging. You can also find free Vector images on this site along with real-life photography.

Biography:

Free, high-quality lifestyle images that you can use to showcase off your startup in all aspects of your online marketing strategy.

Splitshire:

Find exciting photos and videos that you are free to use in your online marketing campaigns. Be sure to check the attribution requirements for content.

New Old Stock:

Specializing in vintage photography, your startup is sure to find all the old school looking photos to meet any need that you might have.

Picjumbo:

free images that feature artistic photos and visually attractive filters that you can use in your blogging strategy.

Life of Pix:

Discover free photos from around the world. The cool thing about this photo resource is that the images cover a range of concepts and topics and all the images have an interesting angle.

Getrefe:

Find fantastic real-world images to showcase your startup’s brand in your online marketing content.

IM Free:

Find all the content you need to build your online presence with IM Free. All of the images that you can find on this site are categorized by different types of Technology, Startups, and icons.

The Pattern Library Find free patterns for your website or other online projects.

ISO Republic:

This is a cool resource for lifestyle images, along with exciting perspectives in each image.

Function:

The author of this website has handpicked their favorite free images so you can skip the manual work of finding the high-quality pictures that you are looking for. Be sure also to check out the free brushes and other helpful tools to ensure the success of your startup marketing campaigns.

Raumrot:

This site draws on free photography assets from various free photo sites. Reduce the time and effort it takes to find the perfect image for your online marketing efforts.

Email Marketing

Email marketing is one of the best marketing channels if you want to **increase sales and build customer trust**. However, it can be challenging to collect and leverage your email marketing list. Here are the **best online marketing tools for small business** if you want to send personalized messages to your entire email list while also saving money.

NEWOLDSTAMP:

If you are looking for an innovative, easy to use, and powerful marketing tool then you will love NEWOLDSTAMP. This tool has a free and paid version so you can create an email signature for you and your team regardless of the email client that you use. You can grab this powerful marketing tool to help expand your reach and drive qualified traffic to your site with professional email signatures!

Contact Form 7:

If you are using WordPress to power your startup website then you should be using Contact For 7. This easy to use contact form plugin allows your audience to send you emails and submit requests straight from your website. The best part is that you can customize the CSS, form content, and other settings like email recipients and confirmation message.

MailChimp:

One of the largest Email Sending Providers (ESP), MailChimp has built their business on working with small business owners. You can register for an account, adjust some settings, and place an email signup form on your website in a matter of minutes.

ManyContactsBar:

You can save time and gain valuable information about people who send you an email from your website using this free script. After someone sends you an email from a contact form on your site, you will receive an email with enriched data. This can help you customize you're follow up the message and save you time from doing manual research on your own.

Hello Bar:

If your startup is looking to grow your email list then you can't miss checking out the Hello Bar. This tool puts a simple bar at the top of your website to engage your audience and lets you test different CTAs and wording. This means that you can feature special offers or other enticing giveaways to get your audience to become qualified leads.

Sumo List Builder:

If you are looking for a complete package one-stop package to power your lead generation efforts than this tool is for you. Everything from popups to subscribe boxes can help you convert prospects into qualified leads. The free version allows for up to 500 subscribers, but this should be a good starting point as you ramp up your startup marketing strategy.

Scroll Triggered Box:

One way to qualify your audience before trying to gather their email address is to know if they are engaged with your content. This free WordPress plugin will show an email subscribe message on your site only after your readers have scrolled a satisfied percent down your page. This means you can

customize your message and trigger the CTA to appear for only people who have read to a specific point of your content.

Sumome Scroll Box:

Scroll Box provides a polite way to ask your customers to get their email address as they finish reading your latest blog article or learning about your goods. This means that you can customize the experience of each user based on their engagement with your content. This approach has shown to be successful compared to showing a signup form at the beginning of your content.

Mailgun:

If you are knowledgeable about coding and customizing APIs then Mailgun is an excellent choice to track and analyze emails in real-time. This program can help your startup understand engagement and other analytics about your email marketing program.

Sendgrid:

Similar to other free ESPs, but this one offers a few more advanced API features out of the box. A good solution if you are trying to save some money while also sending great content to your customers.

Sendinblue:

Another tremendous free ESP- but this one allows you to send up to 9,000 emails a month (compared to the 2,000 cap on many other platforms). This is one of the most simple interfaces, so your startup can send great looking emails without having to worry about wasting time or energy in the process.

Mailtrack:

Whether for your personal Gmail account or your business Google account, it can be tricky to know if your recipients received and viewed an email that you sent them. However, this free add-on allows you to see who opened and read your email in real-time. No more guessing (or excuses) if your recipients received and read your emails!

Canned Emails:

Are you having trouble thinking about how to phrase an email. This free tool provides pre-written email templates that you can use for a variety of interactions. Just keep in mind that these templates are pretty generic, so

you will want to add some customizations and alter the wording based on your needs.

Social Media Management

Social media marketing is a great way to build trust with your customers and **connect with your audience**. However, social media marketing is also a very manual process that requires you to invest lots of time into if you want to see any results. Over the years we have used many social media marketing tools, and we have found the **best online marketing tools for small business social media** that you can use today to save time and reach your goals!

Writeback:

Even when Twitter increased the characters available in each Tweet, many Twitter users need more room to express themselves. This is where Tweetstorms come into play- the group of Tweets from a user to express themselves. However, this can often come off as disjointed, so WriteRack helps organize your thoughts in Tweetstorms by numbering each Tweet, so your audience knows the order and makes interacting with your Tweetstorm more manageable and less cumbersome.

One of the best ways to increase social engagement and improve the reach of your content is to make it easy to share your content on social media. Click To Tweet is a simple to use and efficient way to encourage your readers to share your content on their social networks. There is a WordPress plugin that makes this easier than ever.

Latergram:

Instagram is a great social platform to grow your startup, but the manual labor and work it takes to build an Instagram page can be tiresome. Latergram is a free tool to help you schedule and organize your Instagram content ahead of time so you can focus on engaging with your Instagram audience.

: Have you ever wondered how many times a piece of content or webpage was shared across various social media accounts? You can use How Many Shares to discover the popularity of your online content quickly or do some competitive research to find out how popular content is from your competition.

SocialRank:

As Twitter and Instagram continue to grow, it can be challenging to organize, identify, and manage your followers on these platforms. SocialRank is a great tool to help you optimize your social media networks while also saving valuable time.

Klout:

This is a great tool to understand who your followers are, discover new thought-leaders, and improve your online presence. You can also use your Klout score to know how your content ranks in your industry in a quick and easy format. Plus, Klout is a great tool to find trending content online without having to search for endless blog posts or social media posts.

Ritetag:

Do you want to find the perfect hashtag for your social media post? Or, do you want to discover the best hashtags to rank for on Twitter, Instagram, and Facebook? If so then this free hashtag discovery tool is your perfect solution.

Buffer Free Plan:

Buffer is the best social media planning and scheduling tool on the market. Not only does Buffer allow you to schedule your social content in advance for a wide range of networks, but it also helps you understand how your content is performing with easy to follow analytics. If you choose a social media scheduling tool for your startup, then you should consider using Buffer.

Bitly:

The length of your content matters on social media, and this is even more important on social networks like Twitter. For times when you want to track and analyze engagement on your content, you should think about a tracking tool like Bitly. Just keep in mind that shortened links are starting to show less commitment than naked links, but Bitly is the most trusted link shortening application on the market, so if you choose to shorten your links then you should consider using Bitly.

Addthis:

Making it easy to share your online content is critical if you want your startup to grow. Using an app like Addthis can make it easier than ever for your audience to share your startup information with their network. Simply install this app on your site and let the shares start to grow! Even easier, Addthis has a free WordPress plugin so that you can integrate the fantastic features of your site with almost no effort!

: Just as the name suggestions, SumoMe Share is a simple and easy add-on for your startup website that allows your audience to share your content with ease. The great thing about Sumome Share is that the share buttons come in a variety of options and layouts so you can customize how the buttons look depending on the style of your website or blog.

Disqus:

There are several commenting systems that you can add to your site, but Disqus is one of the best solutions on the market. Not only is Disqus a feature-rich solution, but it is also optimized for SEO purposes. If you want to grow your online community and ensure that Google sees your post with improved interaction, then you should consider installing Disqus on your website or WordPress blog.

Free Survey Creator:

Knowing what your audience wants and customizing your content around the needs of your users is critical if you're going to grow your startup or small business. Free Survey Creator makes it a breeze to generate customized surveys so you can hear feedback from your customers and improve your products or services. The best thing about this program is that you can choose from some ways to implement the surveys on your site-from embedding or links.

Online Surveys & Forms

One of the best ways to improve your products or services is to **hear what your customers think** about what you offer. This feedback is valuable because you can use it to guide improvements and optimize your core business offerings. Finding ways to gather customer input can be complicated, but there are plenty of easy to use **online marketing tools for your small business**.

Typeform:

Typeform is one of the most straightforward survey tools to use, and the minimalist design makes it a breeze for your recipients to share their thoughts with you. Along with looking great, Typeform also allows you to create customized forms to meet your needs.

SurveyMonkey:

SurveyMonkey is the go-to standard for free survey tools. The free version of this tool makes it easy for your startup to create informative surveys with a range of question options. While the free version allows for only ten questions, your startup should be able to gather the information you need with that limitation without an issue.

If you are looking for a simple survey tool, then you can’t go wrong with Google Forms. Not only are the surveys intuitive, but you are also able to embed the poll on your website or send a link to your recipients. While Google Forms is part of the larger Google Suite, so it is very convenient, the form options can be restrictive so you will need to ensure your needs are met.

Batch:

If your startup is developing a mobile application, then Batch could be the best solution for your feedback needs. Unlike many of the other options on this list, Batch is built around mobile notifications that can be pushed to users of your app. This is an excellent choice if you are looking for a simple to use and intuitive survey system to use with your mobile app.

Helprace:

This service stands out from the other options on this list because Helprace is more than just a stand-alone survey tool. While Helprace features a customer survey builder, it also included a more extensive system to help you track your questions, answers, and other information. Think of it as a CRM system that focuses on the question/answer feedback loop. This the perfect tool if your startup is looking to expand into a new market or offer additional products/services so you can understand what your customers want before you invest time and resources.

Miscellaneous Tools

It can be hard to find the best tools to meet **specific needs of your small busine**ss, but there are active communities of entrepreneurs who share their finds and Beta test tools. You can use these small business marketing communities to find the best tools and **see reviews on marketing tools** that are open source and free to use today!

Product Hunt:

If you want to find cutting-edge tools to help your startup grow then Product Hunt is the place for you. This active community shares, comments, and grades new and innovative programs that can help your startup grow. Many of the products featured on Product Hunt are opensource and free to use.

Angellist:

Looking to recruit, invest, or find investors for your startup? Angellist is a great resource to have in your toolkit.

MyPresences:

If you have been in business for any length of time then you know how important it is to have your business listed across the Web. However, being listed isn't enough so you need to make sure that your citations are accurate and consistent. MyPresence can help you accomplish this and ensure that each of those presences is compelling enough that your customers would choose you over your competitors.

Beta List:

Receiving unbiased feedback on your product or service is one of the hardest tasks to accomplish for many startups. Beta List is a passionate community where startups go to share ideas and receive feedback from other entrepreneurs. You can use Beta List to validate your ideas before wasting time or money on an initiative that could fail in the long run.

Startups List: Many startups feel isolated and can lose focus. This list outlines many startups that are based in a city near you!

Erli Bird:

Gain access to a community of 100,000 real-world members who love testing applications. You can submit your startup's application or program to

receive unbiased feedback. This is a must-have tool for your startup if you are developing a mobile app or online resource!

About Author

Bhushan Khairnar is Design Strategist, Investor and mentoring technology based businesses for more than decade. He has been engaged with startups and mature businesses and help them to transform the businesses to grow exponentially. He has founded TGS Frequency, a Design Strategy firm helping businesses to find solution through design thinking and business strategies.

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